Environment Canada | Environnement Canada
Environmental Management | Gestion de l'environnement

CANADA – BRITISH COLUMBIA
OKANAGAN BASIN IMPLEMENTATION AGREEMENT

# NUTRIENT LOADINGS – OKANAGAN BASIN
# REPORT NO. 1

# OKANAGAN RIVER AT PENTICTON
# PRELIMINARY SURVEY AND STATION SELECTION

L.J. ZEMAN, W.E. ERLEBACH
AND H. OLAV SLAYMAKER

DECEMBER 1977

TD
227.B74
OK77-1
c.2

Inland Waters Directorate
Pacific and Yukon Region
Vancouver, B.C.

EL 2031379C
NV8956

BVAE North Van. Env. Can. Lib./Bib.
36 002 177

TD
227
.B74
OK 77-1
c2

CANADA-BRITISH COLUMBIA

OKANAGAN BASIN IMPLEMENTATION AGREEMENT

# NUTRIENT LOADINGS - OKANAGAN BASIN

REPORT NO. 1

## OKANAGAN RIVER AT PENTICTON

## PRELIMINARY SURVEY AND STATION SELECTION

L.J. Zeman, W.E. Erlebach
and H. Olav Slaymaker

LIBRARY
ENVIRONMENT CANADA
PACIFIC REGION

INLAND WATERS DIRECTORATE

VANCOUVER

December 1977

## ABSTRACT

Pilot studies were designed to examine spatial and temporal variations in the concentration of primary nutrients in the 6.6 km reach of Okanagan River connecting Okanagan and Skaha Lakes. Intermittent collection of samples was carried out in July, August, September and December, 1976. The specific objectives of these pilot studies were (a) to obtain preliminary information on point and non-point source contributions to nutrient flux in the Okanagan River-Skaha Lake sub-system, and (b) to find a location for a representative station for long-term monitoring of nutrient loading input to Skaha Lake. To meet these objectives it was necessary to elucidate the nutrient dispersion pattern and the transport below the outfall of the sewage treatment plant serving the town of Penticton and the two Okanagan River tributaries, Shingle and Ellis Creeks.

Asymmetric distribution of streamflow and significantly high concentration gradients of total phosphorus (P), dissolved phosphorus (P), nitrate plus nitrite (N), ammonia (N) and total dissolved nitrogen (N) were observed in the channel cross-sections immediately below the municipal outfall and the two tributary streams. Analysis of variance and multiple range tests indicated that almost complete vertical and lateral mixing of total phosphorus (P) and dissolved phosphorus (P) was achieved at the station located near the airport, approximately 1.7 km downstream from the outfall. Ammonia, which came almost entirely from the municipal outfall, remained highly concentrated along the left bank of Okanagan River. The influence of the outfall was reflected in high concentration of total dissolved nitrogen (N) and its incomplete mixing in the cross-section of the station near the airport. The vertical and lateral mixing of nitrate plus nitrite (N) was incomplete at all channel cross-sections including a station located above the municipal outfall.

A satisfactory sampling station could not be located further downstream because water is backed up in the river channel when the level of Skaha Lake is raised. The station near the airport was, therefore, selected as a representative station for determination of nutrient loadings to Skaha Lake. At this station, it is recommended that samples should be collected periodically from two points on each side of the channel using automatic sequential samplers. Less frequent simultaneous sampling, performed concurrently with appropriate hydrometric measurements, should be done at more points in the channel cross-section. This procedure will allow the determination of nutrient loadings within the limits of an acceptable precision.

## ACKNOWLEDGEMENTS

The pilot studies for the Nutrient Loading Project are a part of the Water Quality Monitoring Program financed under the Canada-British Columbia Okanagan Basin Implementation Agreement.

The contributions of J. Taylor in planning and initiation of the field program as well as the full-time assistance in field measurements and data gathering by D. Walker is greatly appreciated. The professional work of the chemists in the Analytical Service Division, Water Quality Branch, I.W.D. who expeditiously analysed the water samples is gratefully acknowledged. The assistance of the staff of Water Survey of Canada in field hydrometric measurements and in supplying flow data was of major importance to the study.

# LIST OF CONTENTS


| | | Page |
|---|---|---|
| | ABSTRACT | i |
| | ACKNOWLEDGEMENTS | ii |
| | LIST OF CONTENTS | iii |
| | LIST OF FIGURES | v |
| | LIST OF TABLES | vii |
| | INTRODUCTION | 1 |
| ( i) | Objectives of Water Quality Monitoring Program | 1 |
| ( ii) | Overall Objectives of Nutrient Loading Project | 2 |
| (iii) | Specific Objectives of Pilot Studies | 2 |
| 1. | METHODOLOGY | 4 |
| 1.1 | Background | 4 |
| 1.2 | Nutrient Inputs, Outputs and Exchange | 7 |
| 1.3 | Spatial and Temporal Variability | 7 |
| 1.4 | Accuracy and Precision | 10 |
| 1.5 | Loading Determination | 10 |
| 2. | ROUTINE PROCEDURES | 12 |
| 2.1 | Field Measurements | 12 |
| 2.2 | Laboratory Methods | 18 |
| 2.2.1 | Phosphorus | 18 |
| 2.2.2 | Nitrogen | 20 |
| 3. | STUDY AREA | 24 |
| 3.1 | Scope of Study | 24 |
| 3.2 | Pilot Studies | 24 |
| 3.2 | Preliminary Survey | 25 |
| 3.2.1 | General | 25 |

| | | Page |
|---|---|---|
| 3.3.2 | Field Lay-out | 31 |
| 3.3.3 | Statistical Analysis | 34 |
| 3.4 | Results and Discussion | 35 |
| 3.4.1 | Discharge | 35 |
| 3.4.2 | Nutrient Concentration and Load | 36 |
| 3.4.2.1 | Total Phosphorus (P) | 36 |
| 3.4.2.2 | Dissolved Phosphorus (P) | 40 |
| 3.4.2.3 | Nitrate Plus Nitrite (N) | 43 |
| 3.4.2.4 | Ammonia (N) | 46 |
| 3.4.2.5 | Total Dissolved Nitrogen (N) | 46 |
| 4. | SUMMARY | 52 |
| 4.1 | Preliminary Survey | 52 |
| 4.1.2 | Phosphorus | 52 |
| 4.1.3 | Nitrogen | 53 |
| 4.2 | Station Selection - Nutrient Dispersion Study | 54 |
| 4.2.1 | Phosphorus | 54 |
| 4.2.2 | Nitrogen | 57 |
| 5. | CONCLUSIONS AND RECOMMENDATIONS | 60 |
| 6. | REFERENCES | 63 |
| | APPENDIX I | 66 |
| | APPENDIX II | 72 |
| | APPENDIX III | 78 |
| | APPENDIX IV | 84 |
| | APPENDIX V | 90 |

# LIST OF FIGURES


| | | Page |
|---|---|---|
| Figure 1. | Simplified Model for Nutrient Flux in a Lake Ecosystem (from Likens, 1972) | 5 |
| Figure 2. | Photo Mosaic of Okanagan River between Okanagan and Skaha Lakes (Photographs B.C. 7511) | 6 |
| Figure 3. | Okanagan River below the Okanagan Lake Dam, (a) Hydrometric measurements and (b) sequential sampling device (Manning S-4040) for water quality sampling at Station 1. | 13 |
| Figure 4. | Okanagan River near the Penticton Airport. (a) Hydrometric measurements and collection of simultaneous sampling for chemical analysis. (b) Housing of sequential samples located on the left and right river banks at Station 5. | 14 |
| Figure 5. | (a) Replicate samplers and (b) sequential sampling device for collection of samples for chemical analysis. | 16 |
| Figure 6. | Portable Sampling Pump (Masterflex 7015-20). | 17 |
| Figure 7. | Location of Sampling Stations along the Okanagan River reach. Variations in discharge and velocity distribution in the channel cross-section. December 9-10,1976. | 32 |
| Figure 8. | Hydrometric Divisions and Chemical Domains in Channel Cross-section. | 33 |
| Figure 9. | Longitudinal, Lateral and Vertical Variation in Concentration of Total Phosphorus (P). December 9 and 10, 1976. | 37 |
| Figure 10. | Longitudinal, Lateral and Vertical Variation in Concentration of Dissolved Phosphorus (P). December 10, 1976. | 41 |
| Figure 11. | Longitudinal, Lateral and Vertical Variation in Concentration of Nitrate plus Nitrite (N). December 9 and 10, 1976. | 44 |

Page

Figure 12. Longitudinal, Lateral and Vertical Variation in Concentration of Ammonia (N). December 9 and 10, 1976. 47

Figure 13. Longitudinal, Lateral and Vertical Variation of Total Nitrogen (N). December 9 and 10, 1976. 49

# LIST OF TABLES


| | | Page |
|---|---|---|
| Table 1. | Estimated Percentages of Total Phosphorus Loading Entering Skaha Lake, 1969 - 71. (Source: Canada-British Columbia Okanagan Basin Agreement (1974), Tech. Supp. III.) | 9 |
| Table 2. | Precision and Accuracy of Chemical Analysis Total Phosphorus (P) and Dissolved Phosphorus (P). | 19 |
| Table 3. | Precision and Accuracy of Chemical Analysis Nitrate Plus Nitrite (N). | 21 |
| Table 4. | Pilot Studies in the Okanagan River at Penticton, 1976. Mean Concentrations and Standard Deviations at Station 1 and 5. | 27 |
| Table 5. | Pilot Studies in the Okanagan at Penticton, 1976. Mean Nutrient Loadings at Stations 1 and 5. | 28 |
| Table 6. | Pilot Studies, Nutrient Dispersion in the Okanagan River at Penticton, December, 1976. Variation in Total Phosphorus Loading along Investigated River reach. Simultaneous Sampling Method. | 39 |
| Table 7. | Nutrient Dispersion in the Okanagan River at Penticton, December, 1976. Variation in Dissolved Phosphorus Loading along Investigated River reach. Simultaneous Sampling. | 42 |
| Table 8. | Nutrient Dispersion in the Okanagan River at Penticton, December, 1976. Variation in Nitrate Plus Nitrite Loading along Investigated River reach. Simultaneous Sampling Method. | 45 |
| Table 9. | Nutrient Dispersion in the Okanagan River at Penticton, December, 1976. Variation in Ammonia Loading along Investigated River reach. Simultaneous Sampling Method. | 48 |
| Table 10. | Nutrient Dispersion in the Okanagan River at Penticton, December, 1976. Variation in Total Nitrogen Loading along Investigated River reach. Simultaneous Sampling Method. | 51 |

# INTRODUCTION

Federal, provincial and local levels of government have cooperated to develop a program to manage water resources in the Okanagan Basin. In February, 1976, this work culminated with signing of the Canada-British Columbia Okanagan Basin Implementation Agreement. Based on recommendations from the previous Okanagan Basin Study (Canada-British Columbia Okanagan Basin Agreement, 1974) remedial actions had been undertaken to reduce nutrient loads from municipal waste treatment plants with the objective of reducing biological productivity in the main valley lakes. In summer 1976, a program of water quality monitoring was initiated.

## (i) Objectives of Water Quality Monitoring Program

The objectives of the Water Quality Monitoring Program are:

(a) to provide water management with information on the effectiveness of reducing nutrient loads to the mainstem lakes, and

(b) to evaluate the adequacy of the data base on water quality in the basin for decision-making.

The Water Quality Monitoring Program consists of the following components:

(a) Waste Treatment, (B.C. Pollution Control Branch)

(b) Nutrient Loading, (Water Quality Branch, Inland Waters Directorate), and

(c) Lake Response, (Environmental Protection Service, Canada)

The Nutrient Loading Project conducted by Water Quality Branch, IWD, was subdivided into the following components: (a) short-term pilot studies and (b) long-term nutrient monitoring project. The objectives of these components are outlined below.

(ii) Overall Objectives of Nutrient Loading Project

(a) determination of changes in nutrient concentrations downstream from point source,

(b) quantification of nutrient loadings, with acceptable precision, to lakes immediately downstream of treatment plants, and

(c) determination of year-to-year nutrient trends.

In order to achieve the overall objectives of the Nutrient Loading Project a series of short-term pilot studies was initiated in July, 1976.

(iii) Specific Objectives of Pilot Studies

The specific objectives of pilot studies were:

(a) to elucidate nutrient dispersion patterns below the Penticton outfall and the two Okanagan River tributaries, Shingle and Ellis Creeks,

(b) to find a location for a representative station for long-term monitoring of nutrient loading input to Skaha Lake, and

(c) to obtain preliminary information on point and non-point source contributions to the flux of nutrients in the Okanagan River-Skaha Lake sub-system.

The present report deals with pilot studies, conducted in the Penticton area, necessary to establish an approach to the long-term monitoring of nutrient loads to Skaha Lake.

# 1. METHODOLOGY

In order to meet the specific objectives of pilot studies it was necessary to formulate a conceptual framework for the operational stages of these studies and design field procedures for collection of samples and to use appropriate methods for chemical analysis of water samples and data interpretation.

## 1.1 Background

The behaviour of primary nutrients has to be studied within a general context of a mass-flux ecosystem model. The simplified model of this kind, proposed by Likens (1972) is shown in Figure 1. The following components are considered in the model:

(a) Allochthonous nutrient inputs from atmosphere, lithosphere and biosphere.

(b) Autochthonous nutrient exchanges in the forms of (a) available nutrients, (b) organic matter, and (c) primary and secondary minerals.

(c) Storage in deep sediments.

(d) Net nutrient outputs of atmospheric, lithospheric and biospheric origin.

The nutrient concentrations and associated water discharges must be monitored in order to determine mass transport. Both hydrometric and chemical measurements, therefore, were made in the study area of the Okanagan Basin.

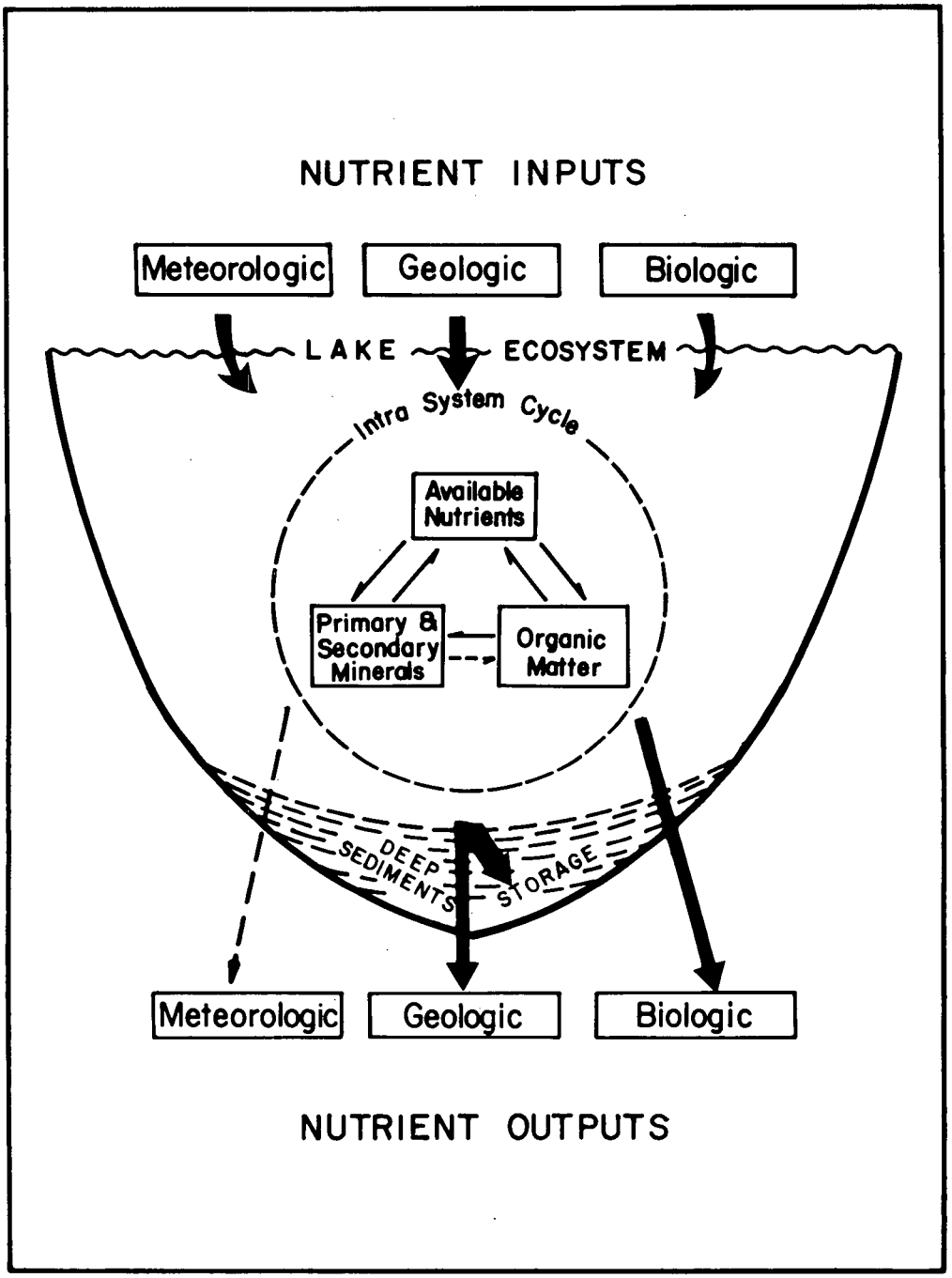



Figure 1. Simplified Model for Nutrient Flux in a Lake Ecosystem (from Likens, 1972)

STATION

1. BELOW THE OKANAGAN DAM
2. BELOW THE PENTICTON OUTFALL
3. BELOW SHINGLE CREEK
4. BELOW ELLIS CREEK
5. NEAR THE PENTICTON AIRPORT

Figure 2. Photo Mosaic of Okanagan River Between Okanagan and Skaha Lakes (Photographs B.C. 7511)

## 1.2 Nutrient Inputs, Outputs and Exchange

The Okanagan River between Okanagan and Skaha Lakes can be related to the following sources, pathways and sinks:

(a) Allochthonous nutrient inputs from: Okanagan Lake, Ellis Creek, Shingle Creek, Penticton waste treatment plant, diffuse sources and direct bulk fallout from the atmosphere.

(b) Autochthonous nutrient exchanges in the form of: turbulent mixing in vertical, lateral and downstream directions, bed and bank sediment and nutrient entrainment, chemical precipitation and adsorption of nutrients and organic sedimentation.

(c) Storage in bed sediments.

(d) Net nutrient outputs measured at the lowest cross-section of the Okanagan River before it enters Skaha Lake and above major backwater effects.

Nutrient sources, both allochthonous and autochthonous must be defined as accurately as possible (Likens, 1972). The estimated percentages of the total phosphorus inputs to Skaha Lake are shown in Table 1 (Canada-British Columbia Okanagan Basin Agreement, 1974). The implied precision of these estimates which were based on chemical measurements made on single water samples is probably not warranted.

## 1.3 Spatial and Temporal Variability

Recent work on Thompson, Okanagan and Squamish Rivers (Oguss and Erlebach, 1976; Kleiber and Erlebach, 1976) has demonstrated the inadequacy of single water samples, taken from

a river, in representing nutrient concentrations in time and over space. Erlebach (1975) stresses the need to establish confidence limits on nutrient loadings and the need for simultaneous sampling to determine short range spatial variation in nutrient concentration. This has been explicitly recognized in the literature previously (Taylor, et al, 1971; Gburek and Heald, 1974; Gale and Demayo, 1974), but there has been little evidence of attempts to modify sampling methodology until the work of Erlebach and his co-workers.

TABLE 1

Estimated Percentages of Total Phosphorus Loadings Entering Skaha Lake, 1969-71

| Source | Percentage |
|---|---|
| Municipal sewage (Penticton) | 59.7 |
| Okanagan Lake (via Okanagan River) | 21.9 |
| Tributary streams (natural sources) | 7.6 |
| Septic tanks (via ground water) | 5.3 |
| Dustfall and precipitation | 3.5 |
| Agriculture (via streams) | 0.7 |
| Septic tanks (via streams) | 0.4 |
| Ground water (natural sources) | 0.3 |
| Industry | 0.3 |
| Storm sewers | 0.2 |
| Ground water (other sources) | 0.1 |
| Total | 100.0 |
| | (24,500 kg from March 1969 to March 1970.) |

Source: Canada-British Columbia Okanagan Basin Agreement (1974) (Technical Supplement III)

## 1.4 Accuracy and Precision

Determination of nutrient loads involves hydrometric and chemical measurements in a river channel. The precision of this determination depends on the number of concentration measurements, local heterogeneity of water composition and spatial and temporal variation of concentration and velocity along the reach of river. The precision and accuracy of both hydrologic and chemical data must be comparable. It is futile to collect quantities of very accurate and precise chemical data, particularly if the hydrologic system is not monitored simultaneously (Taylor, et al, op.cit.).

In this study the requirement for estimates of precision and accuracy necessitated the determination of spatial and temporal variability. In order to determine an appropriate sampling design for long-term monitoring, short-term pilot studies were essential.

The goal of the pilot studies was to establish, at a limited number of sampling stations, the temporal variation of primary nutrient concentrations, and to determine the representativeness of the samples in the river cross-section and river reach. From this information, one can select monitoring stations adequate for determination of nutrient loading to Skaha Lake.

## 1.5 Loading Determination

The concept of nutrient loading in terms of a nutrient added per unit of lake area per unit time was proposed by Sawyer (1947). Vollenweider (1968) has calculated loadings of phosphorus based on population, industry, and land use factors

in a drainage area; he has also defined critical and permissible loadings for lakes as a function of mean depth. Later, Vollenweider (1973) stressed that further parameters should be added to the loading versus mean depth model, particularly flushing rate, internal loading, extent of the shoreline and littoral area. For the Okanagan Basin, the phosphorus and nitrogen loads from major tributary streams to mainstream lakes were estimated by Patalas and Salki (1973). The current trophic state of these lakes in relation to the annual areal loads of total phosphorus was discussed by Stockner and Northcote (1974) and the impact assessment of phosphorus management policies on the eutrophication of Skaha Lake was attempted in Fleming and Stockner (1975).

# 2. ROUTINE PROCEDURES

The description of routine procedures used in the pilot studies includes methods used for hydrometric and chemical measurements in the field as well as methods for chemical analysis of water samples in the laboratory.

## 2.1 Field Measurements

At the cross-section of selected station along the Okanagan River reach (Figure 2) the field measurements consisted of (a) hydrometric measurements, (b) sampling for water chemistry, and (c) pretreatment of samples. During the period of preliminary measurements samples were collected at Station 1 and 2. During nutrient dispersion study hydrometric measurements a collection of samples were conducted at all five stations.

### (a) Hydrometric Measurements

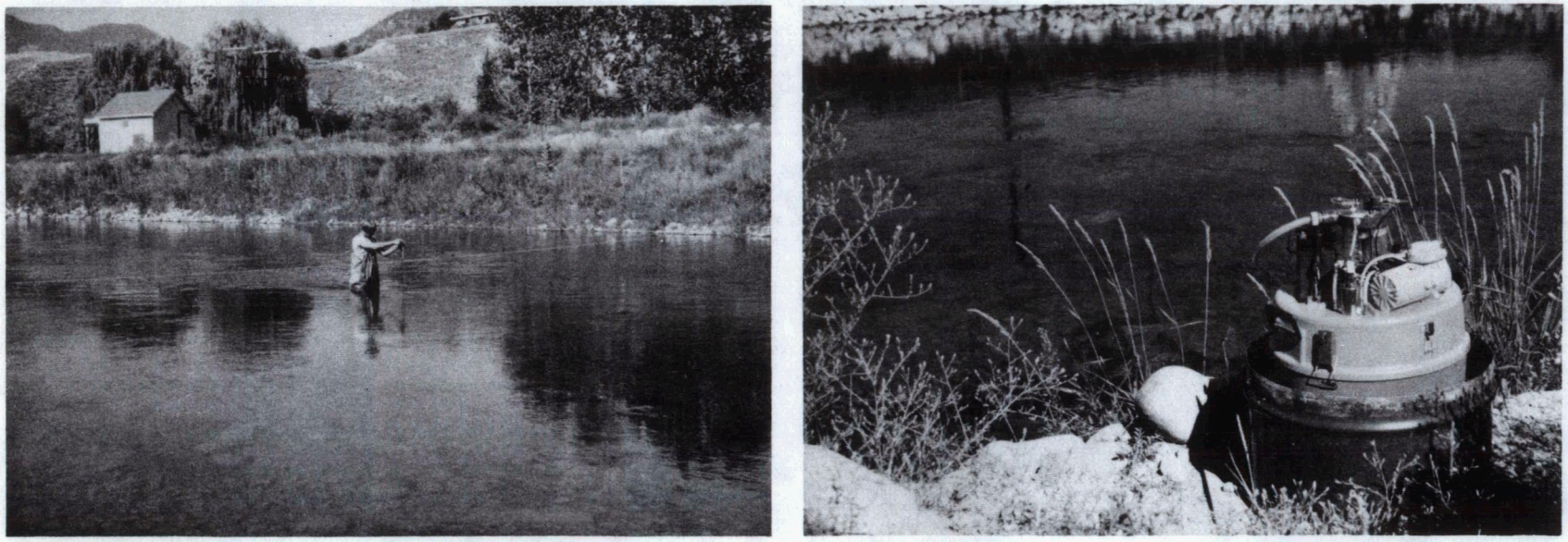
Hydrometric measurements were conducted in cooperation with Water Survey of Canada (Figures 3 and 4) using well established procedures for discharge measurements (e.g. Ozga, 1971).

### (b) Sampling for Water Chemistry

The following two types of samples collection were performed: (i) simultaneous, and (ii) sequential.

#### i. Simultaneous

The replicate samples collected by this method were used for establishing the heterogeneity in nutrient concentrations. Two devices were used for collection of samples: (i) replicate sampler, and (ii) portable sampling pump.



(a) (b)

Figure 3. Okanagan River below the Okanagan Lake Dam (a) Hydrometric measurements and (b) sequential sampling device for water quality sampling at Station 1.

(a) (b)

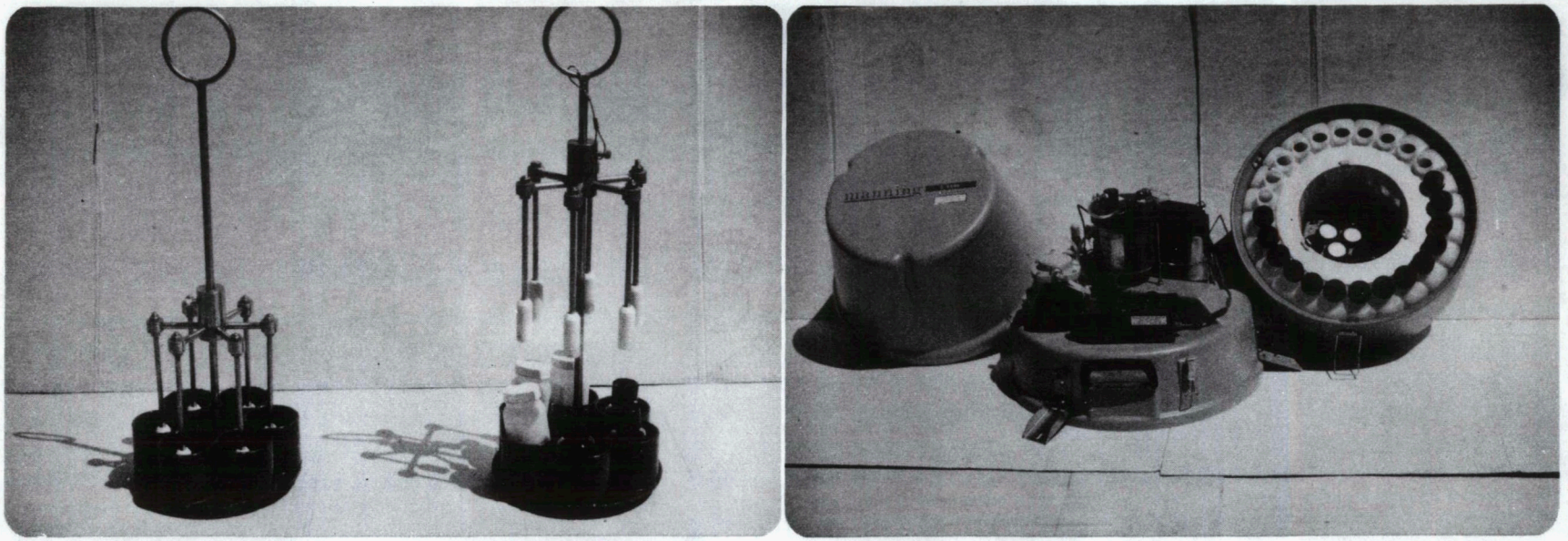
Figure 4. Okanagan River near Penticton Airport. (a) Hydrometric measurements and collection of simultaneous samples for chemical analysis. (b) Housing of sequential samplers located on the left and right river banks at Station 5.

(i) A replicate sampler (Figure 5), developed by Water Quality Branch, IWD, was used for collection of samples from upper stratum of the stream, at approximately 0.2 of the depth of water. Sets of samples for measuring phosphorus concentration were collected in 50 and 100 ml glass-pyrex bottles with bakelite caps over Teflon inserts. Samples for nitrogen analysis were collected in 100 ml polyethylene bottles.

(ii) A portable sampling pump (Masterflex Pump 7015-20), Figure 6, was used for collection of water samples from lower stratum of channel cross-section, at approximately 0.6 of the depth of water.

ii. Sequential Sampling

An automatic sampler (Manning S-4040) was used to collect a series of short-period, discrete samples held in individual plastic containers. This sampling method was intended to provide information on variation of concentrations of chemical constituents with changes in rates of flow and time. Sequential samples were analyzed for the same primary nutrients as samples collected by simultaneous method.



(a) (b)

Figure 5. (a) Replicate samplers and (b) sequential sampling device for collection of samples for chemical analysis.

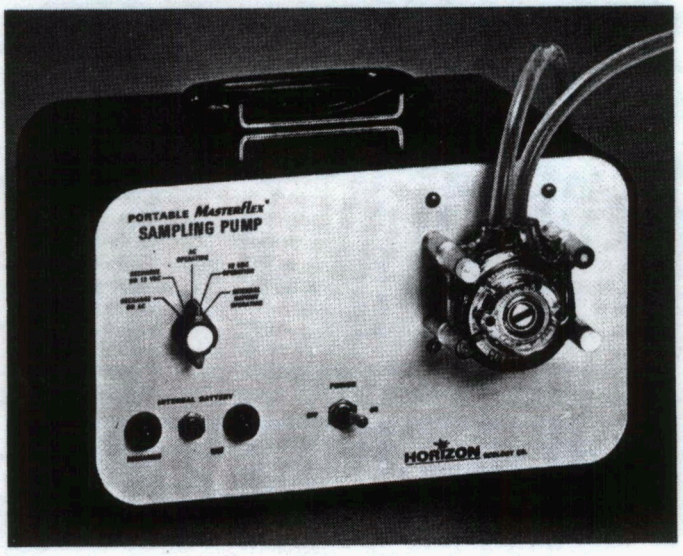



Figure 6. Portable Sampling Pump
(Masterflex 7015-20)

(c) Pretreatment

Water samples collected for the dissolved phosphorus analyses were immediately filtered through the presoaked and prewashed 0.45 micron cellulose acetate membrane filter of 47 mm diameter. Samples for nitrogen determination were kept in coolers (Coleman Coolers Model 5243-720). All samples were shipped to the laboratory in Analytical Service Division, Pacific Region, Water Quality Branch, Vancouver, B.C.

## 2.2 Laboratory Methods

### 2.2.1 Phosphorus

Total phosphorus (P) and dissolved phosphorus (P)

The concentrations of total phosphorus and total dissolved phosphorus were measured by the automated colorometric phosphomolybdate method utilizing ascorbic acid as the reducing agent (Murphy and Riley, 1962).

The same analytical procedure was used on both phosphorus fractions. Samples were digested after the addition of potassium persulfate (0.2g/50mℓ) and 0.5 ml of sulfuric acid (310 ml concentrated $H_2SO_4$/ℓ) for 30 minutes in an autoclave at a pressure of 15 p.s.i. Persulfate under heat and pressure breaks down organically bound phosphorus to orthophosphates. The resulting orthophosphates plus the orthophosphates originally present in the water samples were reacted with ammonium molybdate in the presence of catalyst, antimonyl potassium tartrate, to form heteropolymolybdophosphoric acid. Reduction of this compound with ascorbic acid in aqueous sulphuric acid medium

TABLE 2

Precision and Accuracy of Chemical Analysis

Concentration in mg $\ell^{-1}$

Total Phosphorus (P) and Dissolved Phosphorus (P)

| Sample | Spike | Mean | Standard Deviation | Coefficient of variations | Recovery % |
|---|---|---|---|---|---|
| Low | | 0.0051 | 0.0003 | 6.33 | |
| Medium - 1 | | 0.0131 | 0.0002 | 0.36 | |
| Medium - 2 | | 0.0662 | 0.0004 | 0.64 | |
| High | | 0.1776 | 0.0002 | 0.12 | |
| Low spike | 0.025 +0.025 | 0.0506 | 0.0005 | 0.94 | 101 |
| Medium-1 spike | 0.175 | 0.1882 | 0.0005 | 0.28 | 100 |
| Scale | | 0.002 to 0.2 | | | |
| Detection limit | | 0.002 | | | |

(From Mah, 1976)

produced a molybdenum blue color proportional in intensity to the amount of phosphorus present in the sample. The intensity of the characteristic color of the solution was measured after passing through 880 nm filters. Results were reported as total phosphorus (P) and total dissolved phosphorus (P) in mg $\ell^{-1}$.

The precision and accuracy of the analyses shown in Table 8 were estimated by Mah (1976). Samples of stream water used for this test were collected at four different locations and from these samples seven subsamples were poured from a well mixed sample bottle and analyzed.

2.2.2 Nitrogen

Nitrate plus nitrite

The concentrations of nitrate plus nitrite were measured by the automated cadmium reduction method developed by Technicon Instruments Corporation (1972). An aliquot of the sample was mixed with the ammonimum chloride-ammonium hydroxide buffer solution and passed through a copper-coated cadmium reductor column. In the column, the nitrates were reduced to nitrites. The nitrite ion reacts with sulfanilamide under acid conditions to form a diazo compound. This compound then reacts with N-1-napthyl-ethylene-diamine dihydrochloride and phosphoric acid to form the reddish-purple azo dye. The intensity of the dye was measured spectrophotometrically after passing through 550 nm filters. Nitrate plus nitrite concentrations (N) were reported in mg $\ell^{-1}$, with precision and accuracy shown in Table 3.

TABLE 3

Precision and Accuracy of Chemical Analysis

Concentration in mg $\ell^{-1}$

Nitrate plus Nitrite (N)

| Sample | Spike | Mean | Standard Deviation | Coefficient of Variation | Recovery % |
|---|---|---|---|---|---|
| Low | | 0.0063 | 0.0005 | 7.8 | |
| Medium-1 | | 0.0714 | 0.0005 | 0.8 | |
| Medium-2 | | 0.1134 | 0.0008 | 0.7 | |
| High | | 0.1492 | 0.0015 | 1.0 | |
| Low Spike | 0.005 | 0.0110 | 0.0000 | 0.0 | 100 |
| Medium-1 spike | 0.075 | 0.1464 | 0.0008 | 0.6 | 100 |
| Scale | | 0.002 to | 0.2 | | |
| Detection limit | | 0.002 | | | |

A m m o n i a (N)

| | | | | | |
|---|---|---|---|---|---|
| Low | | 0.0062 | 0.0007 | 11.2 | |
| Medium-1 | | 0.0259 | 0.0016 | 6.1 | |
| Medium-2 | | 0.0589 | 0.0014 | 2.3 | |
| High | | 0.0819 | 0.0009 | 1.1 | |
| Low spike | 0.010 | 0.0167 | 0.0005 | 2.9 | 103 |
| Medium-1 spike | 0.050 | 0.0776 | 0.0011 | 1.5 | 102 |
| Scale | | 0.002 to | 0.2 | | |
| Detection limit | | 0.002 | | | |

Total Dissolved Nitrogen (N)

| | | | | | |
|---|---|---|---|---|---|
| Low | | 0.0256 | 0.0024 | 9.3 | |
| Medium-1 | | 0.2730 | 0.0035 | 1.3 | |
| Medium-2 | | 0.4507 | 0.0035 | 0.8 | |
| High | | 0.8742 | 0.0068 | 0.8 | |
| Low spike | 0.020 | 0.0470 | 0.0018 | 3.9 | 103 |
| Medium-1 spike | 0.500 | 0.7352 | 0.0035 | 0.5 | 95 |
| Scale | | 0.01 to | 1.0 | | |
| Detection limit | | 0.01 | | | |

(From Mah, 1976)

Ammonia

Ammonia was measured by the automated indophenol blue method (Technicon Instruments Corporation, 1971). An aliquot of the sample was treated with an alkaline phenol solution and hypochlorite solution to produce the indophenol blue. The color was intensified by the addition of sodium nitroprusside. The intensity of the colored complex was measured spectrophotometrically after passing through 640 nm filter. Ammonia concentrations were reported as ammonia (N) in mg $\ell^{-1}$, with precision and accuracy indicated in Table 3.

Total dissolved nitrogen

The automated ultra-violet digestion method was used to measure the soluble nitrogen forms in water samples (Afghan et al, 1970; Environment Canada, 1974). The sample was irradiated by an ultra-violet lamp in a quartz coil. The irradiation process was carried out in two stages, because the oxidation of organic compounds in water is pH dependent (Brewer and Riley, 1965). Total dissolved nitrogen (not filtered in field) includes some particulates which are oxidized and dissolved during irradiation. First, an aliquot of the sample was acidified and irradiated in one coil, then the solution was made alkaline and re-irradiated in a second coil. The solution was mixed with disodium EDTA and passed through the cadmium reduction column. A solution composed of sulphanilamide, N-1-naphthyl-ethylene diamine dihydrochlorite and phosphoric acid was added to the sample to form an azo dye. The intensity of the dye was measured spectrophotmetrically after passing through

550 nm filters. Results were reported as total dissolved nitrogen (N) in mg $\ell^{-1}$, with precision and accuracy as indicated in Table 3.

# 3. STUDY AREA

## 3.1 Scope of Study

The subject of this report is the study of phosphorus and nitrogen behaviour over short space and time intervals in the Okanagan River at Penticton.

Because of financial and logistic constraints the study areas in the Okanagan Basin were limited to two areas where changes in nutrient discharges from sewage treatment plants are being made or planned. The areas in the basin affected by these changes are:

(a) Penticton-Okanagan River-Skaha Lake

(b) Oliver-Okanagan River-Osoyoos Lake

The study area at Penticton included the reach of the Okanagan River, the waste outfall and the associated tributary streams between Okanagan and Skaha Lakes (Figure 2). The reach of Okanagan River above Osoyoos Lake and discharges to that reach will be examined in a subsequent report.

## 3.2 Pilot Studies

The pilot studies were conducted in the reach of Okanagan River between Okanagan and Skaha Lakes. This river reach was chosen because the waste treatment plant at Penticton commenced process modifications to remove 80 percent of the phosphorus from waste water in 1972 and there are plans for further removal if warranted. The benefits of further phosphate removal will depend on the relative contribution of nutrients from all sources to Skaha Lake.

Along the reach of Okanagan River below Penticton there are measurement problems which made the selection of a representative station for the monitoring program very difficult. Problems are associated with regulation of flow by the control dam below Okanagan Lake, backwater effect upstream from Skaha Lake and incomplete pollutant mixing downstream of Penticton waste treatment plant.

The Okanagan River flows in a 6612 meter long, man-made, gently curving channel. The flow is regulated by a dam at the exit of Okanagan Lake and by the water surface level of Skaha Lake. Water for irrigation, particularly for the golf course, is taken from the channel.

The channel is a complex pollutant mixing system. Okanagan Lake, the Penticton municipal outfall, and Shingle and Ellis Creeks form discrete sources of pollutants to the main Okanagan channel resulting in an asymmetric distribution of pollutants in channel cross-sections. Flow stratification is reinforced by the occasional backwater effect from Skaha Lake. Shingle and Ellis Creeks flow on highly permeable sand and gravel alluvial fans. Urban runoff and groundwater flow are therefore of importance to the assessment of water quality.

## 3.2 Preliminary Survey

### 3.2.1 General

The aim of the preliminary survey was to obtain some information on spatial and temporal variation of nutrient concentrations in the Penticton area of the Okanagan River reach.

In July, August, September and December, hydrometric and chemical measurements were conducted concurrently at Station 1 (below the Okanagan Lake dam) and at Station 5 (near the Airport). Sampling times were selected to coincide with a number of discharge levels, generally at times of major changes in flow regulated by the Okanagan Lake dam.

Samples were collected by two sampling methods (a) simultaneous and (b) sequential.

(a) a replicate sampler was used to collect simultaneous samples at a number of randomly distributed points across the channel at each station.

(b) an automatic sampling device was used to collect sequential samples in six-hour intervals. At Station 1, one collector was used but at Station 5, one collector was located on the left bank and one collector on the right bank of the river.

3.2.2 Results

Table 4 lists mean nutrient concentrations and their standard deviations, measured during four periods in the summer, fall and winter of 1976 at a station immediately below the dam and a station near the airport.

Table 5 shows the nutrient loadings at the time of sampling calculated from the concentration means.

TABLE 4

Pilot Studies in the Okanagan River at Penticton, 1976
Mean Concentrations and Standard Deviations at Stations 1 and 5

| Sampling Period | Phosphorus Total (P) n | Phosphorus Total (P) mg $\ell^{-1}$ | Phosphorus Dissolved (P) n | Phosphorus Dissolved (P) mg $\ell^{-1}$ | Nitrate Plus Nitrite (N) n | Nitrate Plus Nitrite (N) mg $\ell^{-1}$ | Ammonia (N) n | Ammonia (N) mg $\ell^{-1}$ | Total Dissolved Nitrogen (N) n | Total Dissolved Nitrogen (N) mg $\ell^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| STATION 1 (below Okanagan River dam) | | | | | | | | | | |
| | | | | | Simultaneous Sampling Method | | | | | |
| July 21-24 | 36 | 0.0081<br>0.0021 | 18 | 0.0056<br>0.0009 | 36 | 0.361<br>0.0435 | 36 | 0.0091<br>0.0122 | 36 | 0.1868<br>0.0553 |
| August 21 | 18 | 0.0085<br>0.0050 | | | 18 | 0.0078<br>0.0158 | 18 | 0.0452<br>0.0338 | 18 | 0.2311<br>0.0559 |
| September 14-17 | 54 | 0.0089<br>0.0054 | 18 | 0.0052<br>0.0013 | 108 | 0.0031<br>0.0013 | 108 | 0.0113<br>0.0064 | 108 | 0.1997<br>0.0263 |
| December 9-10 | | 0.0079<br>0.0024 | | 0.0050<br>0.0009 | | 0.0390<br>0.0076 | | 0.0060<br>0.0046 | | 0.1960<br>0.0172 |
| | | | | | Sequential Sampling Method | | | | | |
| December 9-11 | | | | | 47 | 0.0387<br>0.0019 | 47 | 0.0123<br>0.0205 | 47 | 0.1975<br>0.0299 |
| STATION 5 (near the Airport) | | | | | | | | | | |
| | | | | | Simultaneous Sampling Method | | | | | |
| July 22-24 | 72 | 0.0107<br>0.0026 | | | 72 | 0.0492<br>0.0881 | 72 | 0.0968<br>0.0436 | 72 | 0.2903<br>0.1245 |
| August 21 | 18 | 0.0102<br>0.0038 | | | 18 | 0.0084<br>0.0044 | 18 | 0.1065<br>0.0641 | 18 | 0.2832<br>0.0711 |
| September 14-17 | 144 | 0.0106<br>0.0052 | 48 | 0.0076<br>0.0032 | 288 | 0.0092<br>0.0038 | 288 | 0.0670<br>0.0296 | 288 | 0.2630<br>0.0468 |
| | | | | | Sequential Sampling Method | | | | | |
| | | | | | Left Bank | | | | | |
| September 14-18 | | | | | 92 | 0.0109<br>0.0023 | 92 | 0.1171<br>0.0319 | 92 | 0.3086<br>0.0384 |
| | | | | | Right Bank | | | | | |
| | | | | | 25 | 0.0044<br>0.0009 | 25 | 0.0383<br>0.0123 | 25 | 0.1942<br>0.0140 |
| | | | | | Simultaneous Sampling Method | | | | | |
| December 9-10 | 48 | 0.0106<br>0.0021 | 24 | 0.0070<br>0.0016 | 96 | 0.0445<br>0.0044 | 96 | 0.1158<br>0.0557 | 96 | 0.3156<br>0.0638 |
| | | | | | Sequential Sampling Method | | | | | |
| | | | | | Left Bank | | | | | |
| December 9-11 | | | | | 32 | 0.0457<br>0.0019 | 32 | 0.1834<br>0.0735 | 32 | 0.3347<br>0.0462 |
| | | | | | Right Bank | | | | | |
| | | | | | 48 | 0.0409<br>0.0027 | 48 | 0.0384<br>0.0178 | 48 | 0.2231<br>0.0183 |

Note: n is the number of observations.
upper figure indicates mean concentration, lower figure is standard deviation.

TABLE 5

Pilot Studies in the Okanagan River at Penticton, 1976
Mean Nutrient Loadings at Stations 1 and 5

| Sampling Period | Discharge $m^3 s^{-1}$ | Phosphorus Total (P) kg $day^{-1}$ | Phosphorus Dissolved(P) kg $day^{-1}$ | Nitrate plus Nitrite (N) kg $day^{-1}$ | Ammonia (N) kg $day^{-1}$ | Total Dissolved Nitrogen (N) kg $day^{-1}$ |
|---|---|---|---|---|---|---|
| STATION 1 (below Okanagan River dam) | | | | | | |
| | | | Simultaneous Sampling Method | | | |
| July 21 | 3.48 | 2.4 | 1.6 | 15.1 | 4.4 | 61.7 |
| July 22 | 42.90 | 30.8 | | 118.9 | 37.4 | 647.2 |
| July 23 | 42.76 | 27.7 | | 92.7 | 22.9 | 644.7 |
| July 24 | 42.76 | 30.7 | | 137.4 | 20.3 | 725.3 |
| August 21 | 27.83 | 20.4 | | 18.8 | 108.7 | 555.8 |
| September 14-17 | 27.72 | 21.3 | 12.6 | 7.4 | 27.1 | 478.4 |
| December 9-10 | 26.75 | 18.3 | 11.6 | 90.2 | 13.8 | 453.5 |
| | | | Sequential Sampling Method | | | |
| December 9-11 | 28.17 | | | 94.0 | 29.9 | 480.8 |
| STATION 5 (near the Airport) | | | | | | |
| | | | Simultaneous Sampling Method | | | |
| July 22-24 | 47.76 | 39.5 | | 182.2 | 357.7 | 1072.6 |
| August 21 | 28.83 | 24.5 | | 20.2 | 256.2 | 681.2 |
| September 14-18 | 28.60 | | | 26.9 | 289.4 | 762.6 |
| | | | Sequential Sampling Method | | | |
| September 14-18 | | | | 37.8 | 191.9 | 621.2 |
| December 9-10 | 28.65 | 26.5 | 17.3 | 110.4 | 287.1 | 781.6 |
| December 9-11 | 28.67 | | | 107.3 | 274.7 | 690.9 |

Note: At Station 1, loads in July are listed separately for each sampling day because of the occurrence of significant changes in flow and nutrient concentrations.
At Station 5, data on loadings represent arithmetic averages of measurements along left and right bank of the channel.

Total phosphorus (P) and dissolved phosphorus (P) at Station 1 show consistent concentrations during the sampling periods even when discharge was changed markedly. Since the water is almost directly from the lake, one would not expect discharge to significantly effect variation in concentrations of these constituents. Downstream, between Stations 1 and 5, concentrations of total and dissolved phosphorus increased presumably because of the influence of the Penticton outfall, and Shingle and Ellis Creeks. The influence of variable nutrient sources, point and non-point sources, along this river reach was further elucidated during the pollutant dispersion study conducted in December, 1976.

Nitrate plus nitrite (N) concentrations show an apparent monthly decrease (July, August and September) and an increase in December. The concentration of ammonia (N) was variable and low at Station 1. On the other hand, at Station 5, concentrations were significantly higher than at Station 1.

By averaging the loading data for the period of preliminary measurements, the loads of total phosphorus were in the range from 2.4 to 30.8 kg $day^{-1}$ at Station 1 and in the range of 24.5 to 39.5 kg $day^{-1}$ at Station 5. The limited data on dissolved phosphorus show very high increase of this phosphorus form downstream.

Loadings of nitrate plus nitrite for the sampling period were in the range from 7.4 to 137.4 and from 20.2 to 182.2 kg $day^{-1}$ at Stations 1 and 5, respectively. Ammonia loadings were in the range from 4.4 to 108.7 and from 101.9 to 357 kg $day^{-1}$

at Stations 1 and 5, respectively. Average total nitrogen loadings were in the ranges from 61.7 to 725.3 and from 621.2 to 1072.6 kg $day^{-1}$ at Station 1 and 5, respectively. The high total nitrogen loadings suggest that approximately 80 percent at Station 1 and approximately 50 percent at Station 5 of this nitrogen form is made up of organic nitrogen (after subtraction of inorganic forms from the total nitrogen).

## 3.3 Station Selection-Nutrient Dispersion Study

### 3.3.1 General

The assumption often made in environmental studies, that properties of the water do not vary within a stream cross-section or along the stream axis, is not normally valid. If the water environment is to be managed soundly, the overall mixing and transport processes must be understood (Sayre, 1973). Studies of pollutant dispersion necessarily involve detailed hydrometric measurements concurrently with water chemistry sampling. The following factors must be recognized: (a) non-uniformity of flow in open channels, (b) asymmetrical shear stress distribution in the channel cross-section, and (c) the phenomena of secondary flow and turbulence. The mean mixing properties of a stream can be defined in terms of (a) a longitudinal dispersion coefficient, (b) a vertical mixing coefficient, and (c) a transverse mixing coefficient. These coefficients show spatial and temporal variation because of the above hydraulic factors and because the degree of mixing achieved at each cross-section is a function of discharge, river channel geometry, nature and location of tributary sources and the conservativeness of the pollutant.

3.3.2 Field Lay-out

The longitudinal dispersion of nutrient concentrations, their lateral and vertical mixing in the Okanagan River reach below the Penticton outfalls, was examined on December 9 and 10, 1976. Five sampling stations were established along the Okanagan River reach connecting Okanagan and Skaha Lakes. These temporarily established stations were used for hydrometric measurements and collection of chemical data. The locations of the stations were defined in terms of distances downstream from the Okanagan River control dam (Figure 7).

At each of five stations, measurements were taken in the hydrometric divisions and chemical domains of channel cross-section.

(a) Hydrometric Divisions

The channel cross-section was divided into a number of verticals and sub-sections (Figure 8).

Verticals. Verticals were located at equivalent intervals from water's edge at the left bank to the right bank. All measurements of water depth and velocity were made at these verticals.

Sub-Sections. Sub-sections were determined by boundaries located mid-way between verticals and by the upper and lower limits of water columns.

(b) Chemical Domains

For the purpose of chemical measurements a channel cross-section was divided into areal units as described below. Each chemical measurement was assumed to represent the quality in the upper and lower portion of a

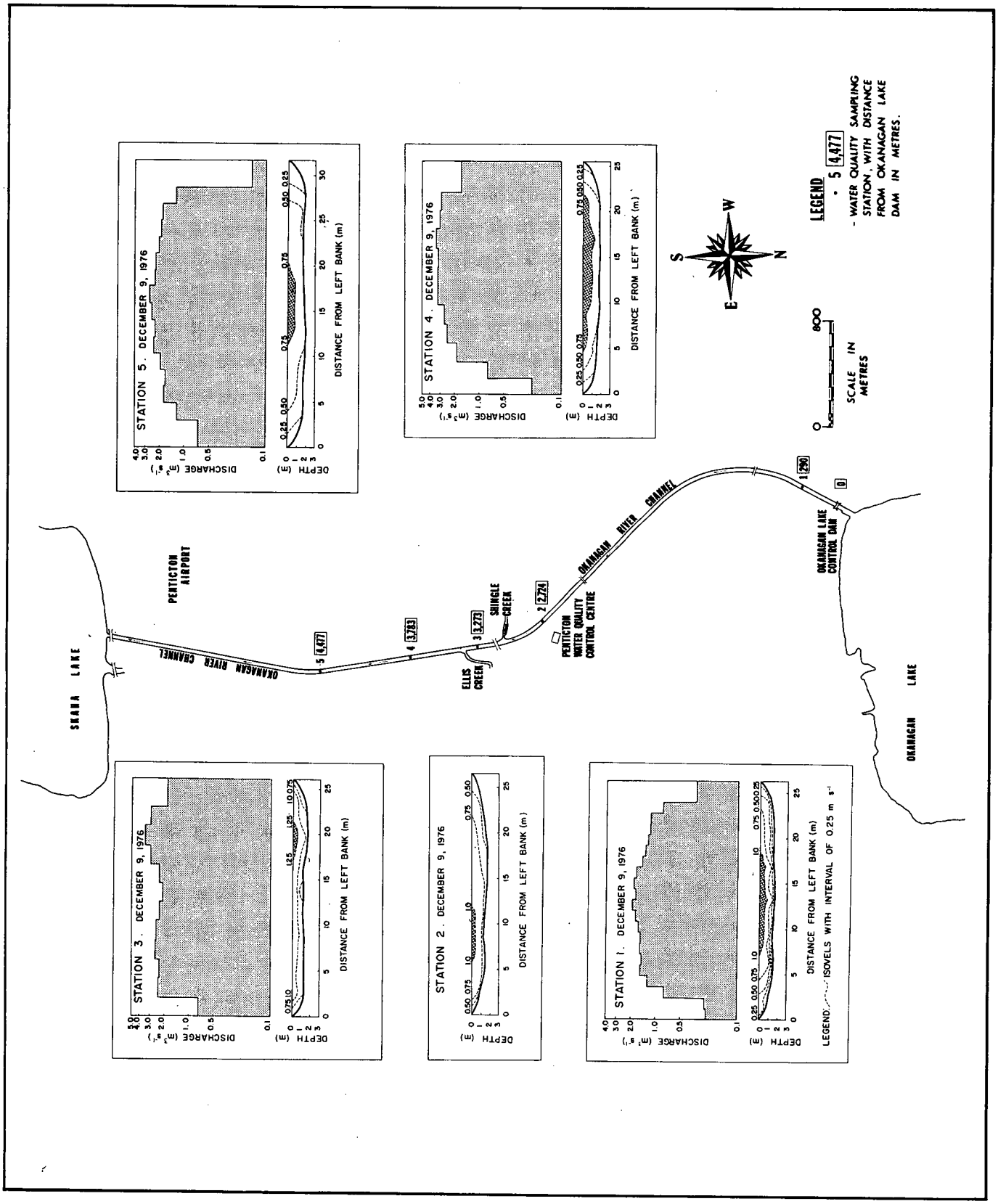



Figure 7. Location of Sampling Stations along the Okanagan River reach. Variation in discharge and velocity distribution in the channel cross-section. December 9 to 10, 1976.

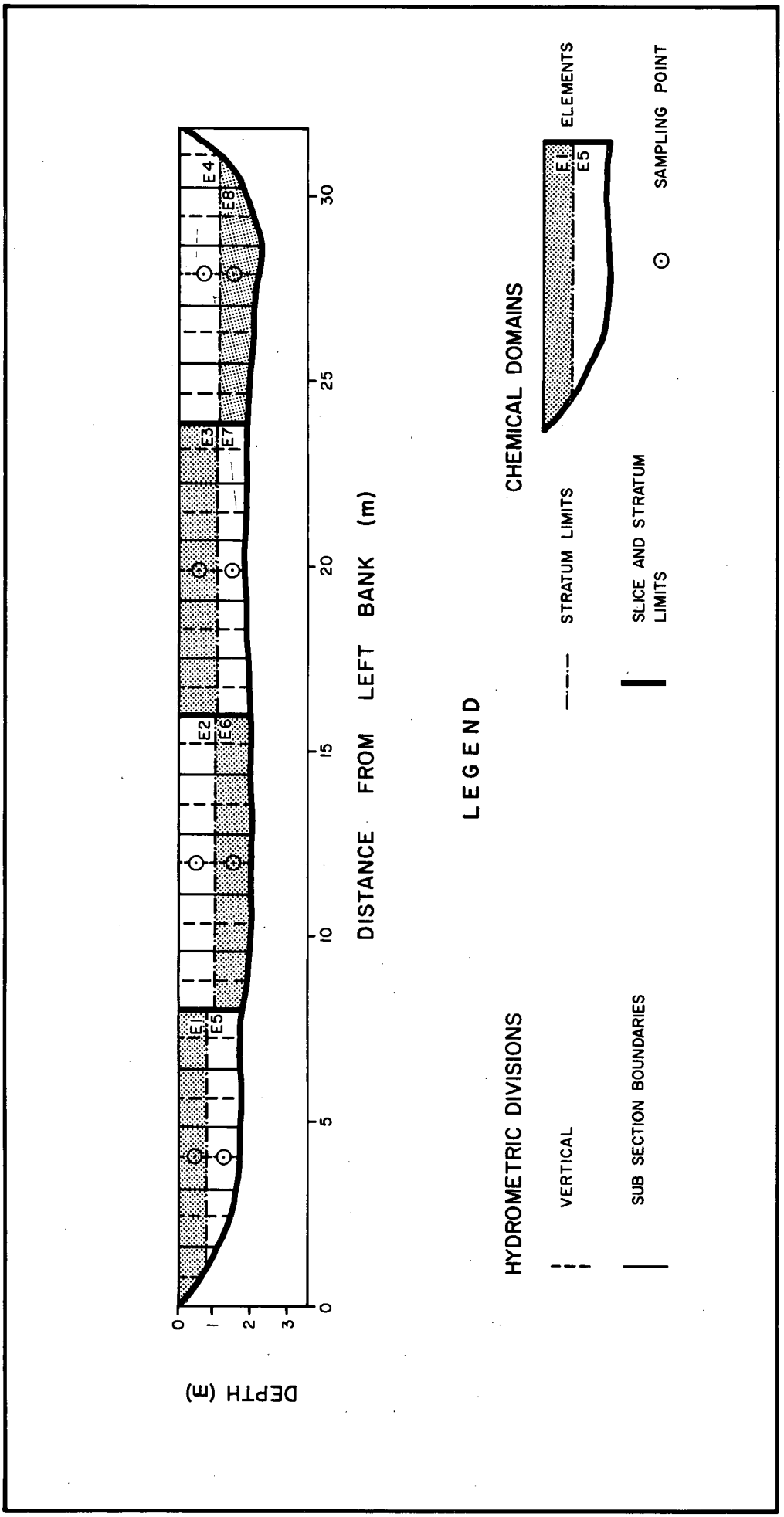



Figure 8. Hydrometric Divisions and Chemical Domains in Channel Cross-section.

group of subdivisions.

Strata. Strata were horizontal subdivisions of cross-sections, representing chemical domains for the assessment of vertical pollutant mixing. Hereafter, these units were referred to as upper and lower strata.

Slices. Slices were lateral subdivisions of cross-section, commonly four in number, which incorporated a number of sub-sections. Slices represented chemical domains for the assessment of lateral pollutant mixing.

Elements. Elements were the smallest areal units of the cross-section, defined by the stratum and slice boundaries, and the upper and lower water surface.

### 3.3.3 Statistical Analysis

Measurements of nutrient concentrations obtained from the pilot study conducted during December 9 and 10, 1976, were subjected to analysis of variance. The overall test involving data measured in the chemical domains of all stations, during two days, indicated significant differences between stations and within sampling days. A fixed analysis of variance model was, therefore, applied separately to data for each day and to individual stations.

The analysis of variance model (Scheffé, 1969) for this case was:

$$Y_{ij} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ij}$$

where $\mu$ denotes the effect common to every observation, i.e. the general mean of Y, $\alpha$ is the effect common to every observation in the i th slice, $\beta$ is the effect common to every

observation in the j th stratum, $\alpha\beta$ is the interaction term and $\varepsilon$ is the error term.

At a particular station, when the analysis of variance indicated significant differences between data collected in these domains, and if the interaction between areal elements and slices was significant the Tukey's Multiple Range Test was used (Miller, 1966). This test sorted slices and elements into groups whose means were not significantly different. Results are shown in Appendices I, II, III, IV and V.

## 3.4 Results and Discussion

### 3.4.1 Discharge

Discharge during the days of sampling, December 9 and 10, 1976, was regulated to remain essentially constant at Station 1 (below Okanagan Lake dam). Along the investigated part of the Okanagan River reach the discharge increased from 26.75 $m^3s^{-1}$ at Station 1 to 28.67 $m^3s^{-1}$ at Station 5 (near the Penticton Airport). This 7 percent increase resulted from the contribution of the Penticton waste treatment plant, Shingle Creek and Ellis Creek.

The plot of discharge and velocities (Figure 7) versus distance from left bank of the river indicated that the flow was symmetrical at Station 1 and approximately symmetrical at Station 5. On the other hand, at Station 2 (below Penticton municipal outfall) velocity distribution was asymmetrical. The asymmetry in distribution of both the discharge and velocity was further evident at Station 3 (below Shingle Creek) and Station 4 (below Ellis Creek).

This asymmetry in channel flow reduces the accuracy of discharge determination for the following reasons: (a) an error in the determination of one sub-section discharge has a disproportional effect on the accuracy of the total discharge determination and (b) asymmetry of flow commonly indicates presence of meandering thalweg (line of maximum depth of flow) and this in turn indicates cross-sectional instability (Leopold, et al., 1964). Some improvement in accuracy of flow determination could be achieved by reducing the size of the sub-sections in the region of high discharge.

The observations obtained in this Okanagan River reach imply that Stations 2, 3 and 4 would not be suitable for long-term hydrologic monitoring. At Station 5, however, to confirm the approximately symmetrical discharge pattern, further measurements will be required during a greater range of flows.

### 3.4.2 Nutrient Concentration and Load

#### 3.4.2.1 Total Phosphorus (P)

The concentration of total phosphorus exhibited pronounced longitudinal, lateral and vertical variations along the Okanagan River reach. There was a significant variation in concentrations of this constituent between stations as well as within days of sampling for chemical analysis. The plots (Figure 9) illustrating the 95 percent confidence limits around the concentration mean indicated high variations of point measurements of total phosphorus concentrations at all stations, even at Station 1. This could result from the heterogeneity of particulate phosphorus kept in suspension by the

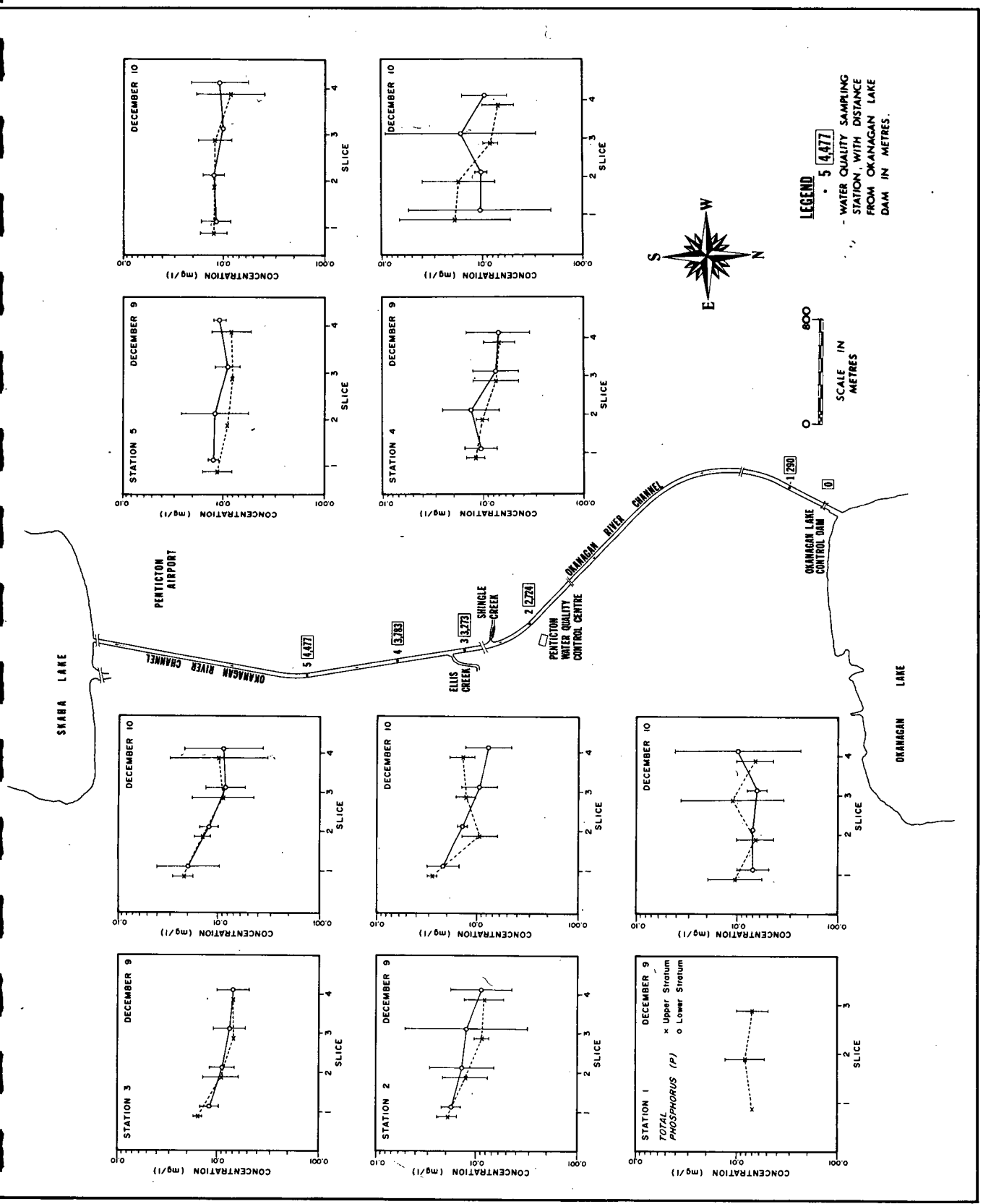



Figure 9. Longitudinal, lateral and vertical variation in concentration of total phosphorus (P), December 9 and 10, 1976. Original observations were transformed logarithmically ($\log_{10}$) and confidence intervals around geometric mean concentrations are shown on logarithmic scale.

turbulent flow. As indicated by the confidence limits, the tributary streams appeared to increase this heterogeneity.

The cross-sectional asymmetry of the flow distribution observed at stations below the outfall and the two tributary streams was accompanied by the significant, lateral variation in total phosphorus concentrations. As shown in Figure 9, vertical variations were very pronounced particularly at the stations located below outfall and Ellis Creek. At Station 5, the lateral mixing process was almost complete on December 9 and complete on December 10, as indicated by the analysis of variance and multiple range test (Appendix 1). At this station, there was no significant concentration difference between sampling points located in the two strata of the channel cross-section on December 10.

It can be concluded, that within the limits of the analysis of variance and multiple range tests (Appendix I), the measurements of concentration indicated that lateral mixing was nearly complete on December 9 and complete on December 10, and vertical mixing was complete on December 10 at the Station 5, located 1.75 km downstream from the Penticton municipal outfall.

The measured discharge data and concentration means obtained at the channel cross-section of each station were used for the calculation of loads (Table 6) on each of the two days. The differences in loads between stations and within day varied considerably. The greatest between-station load increase of total phosphorus by 71 to 73 percent, occurred between Stations

TABLE 6

Nutrient Dispersion in the Okanagan River at Penticton, December 1976

Variation in Total Phosphorus Loading along Investigated River Reach

Simultaneous Sampling Method

| | Station | December 9 and 10 Discharge $m^3 s^{-1}$ | Increase by Station % | December 9 Load kg $day^{-1}$ | Increase by Station % | December 10 Load kg $day^{-1}$ | Increase by Station % |
|---|---|---|---|---|---|---|---|
| 1 | Below Okanagan Lake dam | 26.75 | | 17.11 | | 19.42 | |
| 2 | Below the Penticton municipal outfall | 26.75 (est) | 0 | 29.59 | 73 | 33.29 | 71 |
| 3 | Below Shingle Creek | 28.26 | 6 | 22.71 | -24 | 31.98 | - 4 |
| 4 | Below Ellis Creek | 28.34 | 0 | 23.26 | 2 | 32.32 | 1 |
| 5 | Near the Penticton Airport | 28.67 | 1 | 25.02 | 8 | 27.99 | -13 |
| | 1 and 5 | | 7 | | 46 | | 44 |

Note: Percentages were reduced to nearest integer.

1 and 2. The net increase along the investigated river reach was in the range of 44-46 percent as determined between Stations 1 and 5.

It can be expected that variation between daily loading rates will be even more pronounced during variation in flow in the whole water year. Information on loading to Skaha Lake, within acceptable precision limits, will therefore become available after the daily loading rates have been determined from continuous monitoring of nutrient loads.

3.4.2.2 Dissolved Phosphorous (P)

In comparison with total phosphorus, dissolved phosphorus showed a smaller, but significant increase in concentration at the station located below the Penticton outfall (Figure 10). Downstream from the outfall, the variations in dissolved phosphorus concentration in cross-sections of all stations were less pronounced than those of total phosphorus. Stations 4 and 5 show complete lateral mixing.

The load of dissolved phosphorus significantly increased by 24 percent, between Stations 1 and 2 (Table 7). There was further significant load increase of this constituent along the river reach below the confluence of the two tributary streams. The net increase between Stations 1 and 5 was about 50 percent.

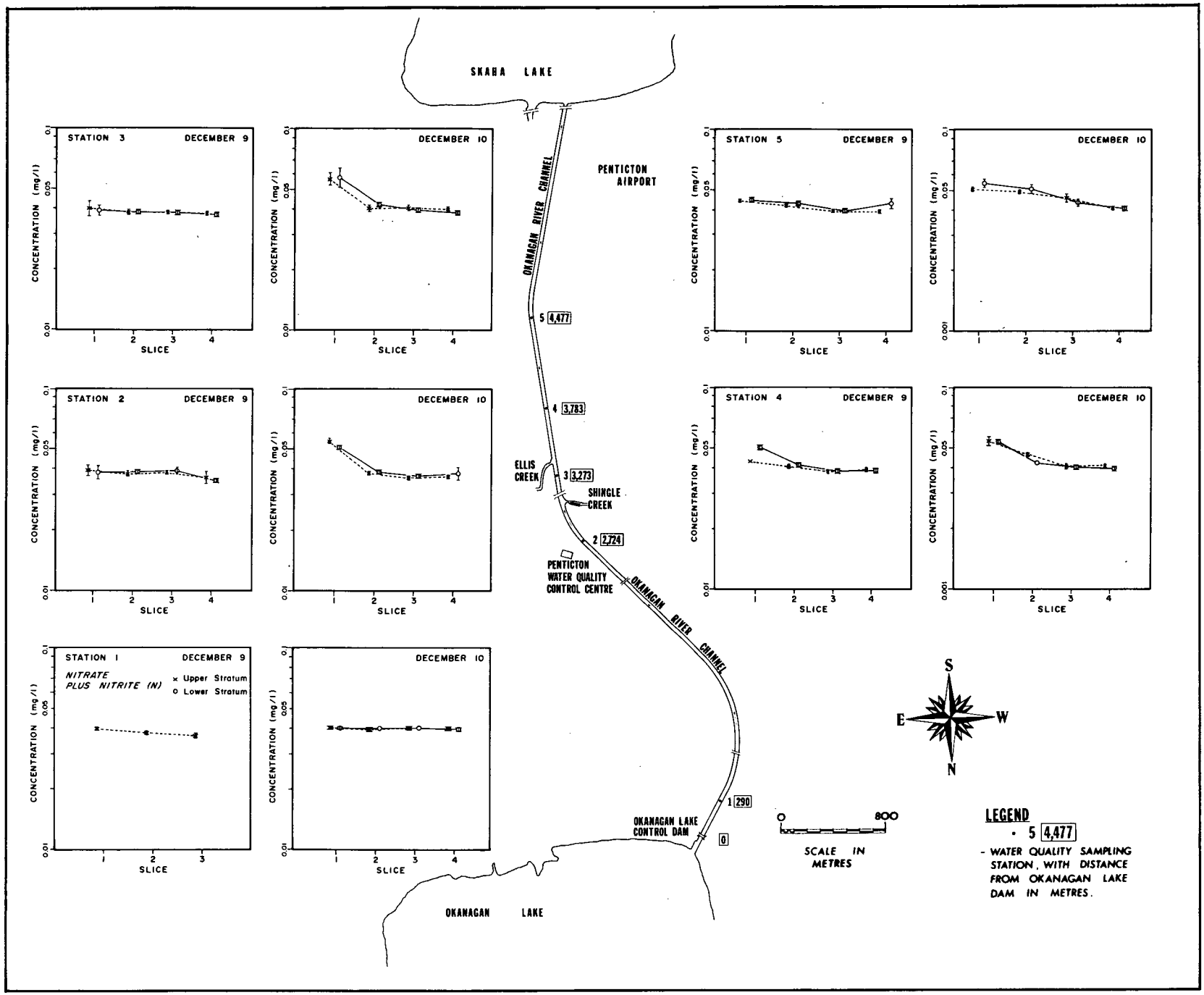



Figure 10. Longitudinal, lateral and vertical variation on concentration of dissolved phosphorus (P), December 10, 1976. Original observations were transformed logarithmically ($\log_{10}$) and confidence intervals around geometric mean concentrations are shown on logarithmic scale.

TABLE 7

Nutrient Dispersion in the Okanagan River at Penticton, December 1976

Variations in Dissolved Phosphorus Loading along Investigated River Reach

Simultaneous Sampling Method

| | Station | Discharge $m^3 s^{-1}$ | Increase by Station % | Load kg $day^{-1}$ | December 10 Increase by Station % |
|---|---|---|---|---|---|
| 1 | Below Okanagan Lake dam | 26.75 | | 11.56 | |
| 2 | Below the Penticton municipal outfall | 26.75 (est) | 0 | 14.33 | 24 |
| 3 | Below Shingle Creek | 28.26 | 6 | 16.85 | 18 |
| 4 | Below Ellis Creek | 28.34 | 0 | 17.38 | 3 |
| 5 | Near the Penticton Airport | 28.67 | 1 | 17.34 | -0.2 |
| | 1 and 5 | | 7 | | 50 |

Note: Percentages were reduced to nearest integer.

Loads of particulate phosphorus can be estimated by subtracting the dissolved phosphorus from the total phosphorus. About 10 to 20 kg $day^{-1}$ less of particulate phosphorus apparently passes the airport station than passes the station below the outfall. This difference may be accounted for by dissolution or sedimentation of the particulates. Since the dissolved phosphorus, relative to the total phosphorus, shows a small increase, approximately 3 kg $day^{-1}$, some deposition of particulates on stream bed above Station 5 could be expected.

3.4.2.3 Nitrate plus Nitrite (N)

The concentrations of nitrate plus nitrite showed the smallest variation of all the nitrogen forms analysed. The narrowness of confidence limits (Figure 11) leads to the result that small lateral differences in concentration of this nitrogen form are statistically significant (Appendix III). Thus, the statistical analysis indicates incomplete mixing even at the station located below the Okanagan Lake dam. Inspection of the plot (Figure 11) suggests that the lateral variation in concentration of nitrate plus nitrite was more evident at the Stations 2, 3 and 4 than at Station 5.

In terms of loads, the increase of nitrate plus nitrite was accounted for by the combined effect of the tributary creeks, approximately 15 percent, with respect to Station 2 (Table 8). Along the Okanagan River reach the net load increase on the two days was approximately 19 and 25 percent.

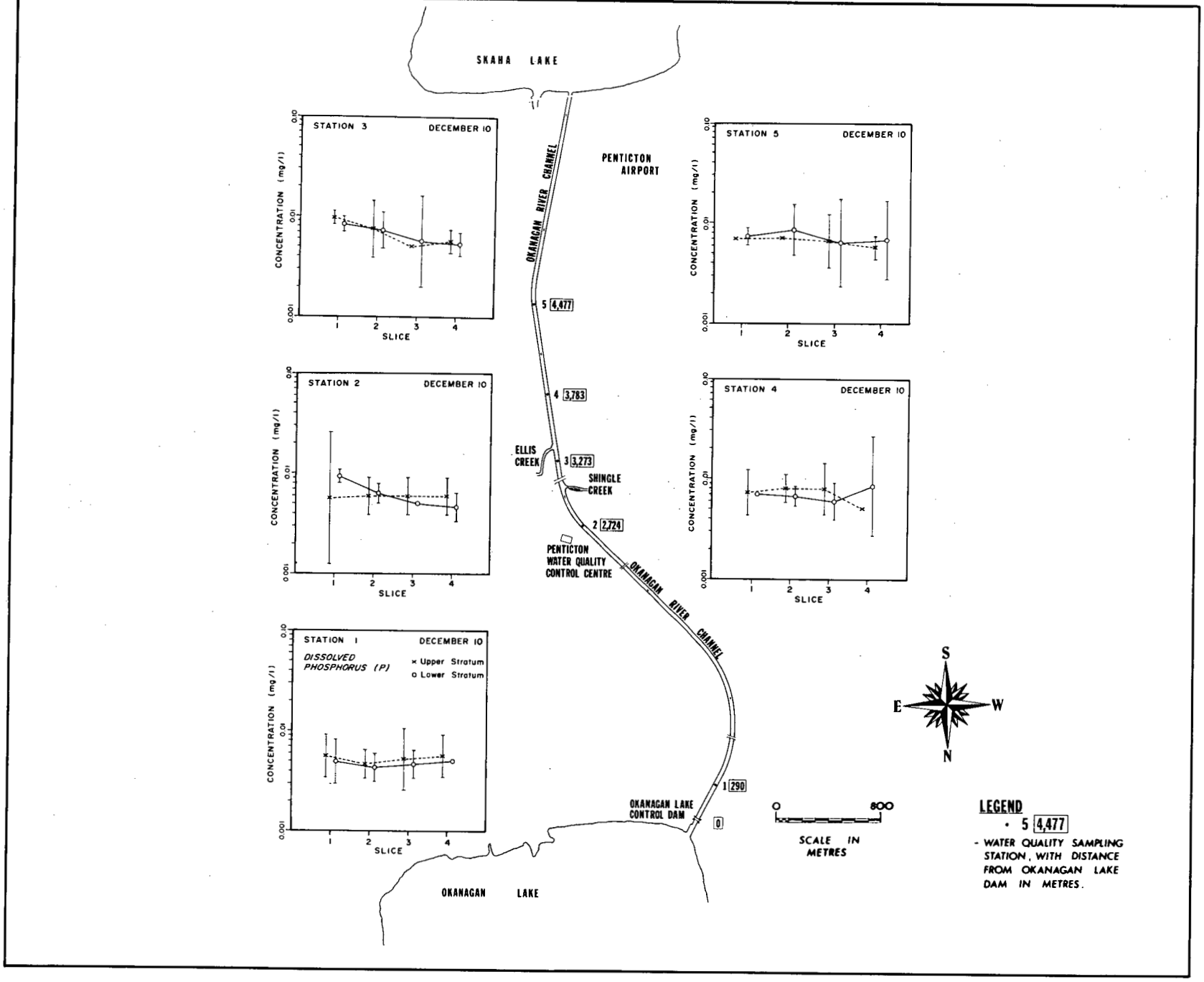



Figure 11. Longitudinal, lateral and vertical variation in concentration of nitrate plus nitrite (N), December 9 and 10, 1976. Original observations were transformed logarithmically ($\log_{10}$) and confidence intervals around geometric mean concentrations are shown on logarithmic scale.

TABLE 8

Nutrient Dispersion in the Okanagan River at Penticton, December 1976

Variation in Nitrate Plus Nitrite Loading along Investigated River Reach

Simultaneous Sampling Method

| | Station | December 9 and 10 Discharge $m^3 s^{-1}$ | December 9 and 10 Increase by Station % | December 9 Load kg $day^{-1}$ | December 9 Increase by Station % | December 10 Load kg $day^{-1}$ | December 10 Increase by Station % |
|---|---|---|---|---|---|---|---|
| 1 | Below Okanagan Lake dam | 26.75 | | 88.07 | | 92.23 | |
| 2 | Below the Penticton municipal outfall | 26.75 (est) | 0 | 87.15 | - 1 | 95.01 | 3 |
| 3 | Below Shingle Creek | 28.26 | 6 | 93.99 | 8 | 108.16 | 14 |
| 4 | Below Ellis Creek | 28.34 | 0 | 100.64 | 7 | 109.21 | 1 |
| 5 | Near the Penticton Airport | 28.67 | 1 | 105.03 | 4 | 115.69 | 6 |
| | 1 and 5 | | 7 | | 19 | | 25 |

Note: Percentages were reduced to nearest integer.

3.4.2.4 Ammonia (N)

The most obvious feature of the behaviour of ammonia concentration in the Okanagan River reach are the steep lateral gradients across the channel, particularly at the station located below the municipal outfall (Figure 12). On December 10, there was an increase in mean ammonia concentration from 0.0007 mg $\ell^{-1}$ at Station 1 to 0.22 mg $\ell^{-1}$ at Station 2, with maximum of 0.615 mg $\ell^{-1}$ observed at the left bank of Station 2 (Appendix IV). The mean concentrations of ammonia were still high at all stations located downstream, but at Station 5 the lateral concentration gradient in the channel cross-section was markedly reduced. It became evident that to achieve complete mixing of ammonia, coming dominantly from the municipal outfall, a considerably longer river reach would be required.

Ammonia loads below the Penticton municipal outfall were high (Table 9) and remained high at Station 5. The net increase in ammonia load between Stations 1 and 5 ranged from approximately 1,620 to 2,620 percent. It would be reasonable to conclude that much of the measured ammonia load reaches Skaha Lake.

3.4.2.5 Total Dissolved Nitrogen (N)

The concentration of total dissolved nitrogen was uniformly distributed in channel cross-section at Station 1 (Figure 13). The substantial concentration gradients for this constituent in the cross-sections of all stations downstream was attributable to the ammonia. The total dissolved nitrogen

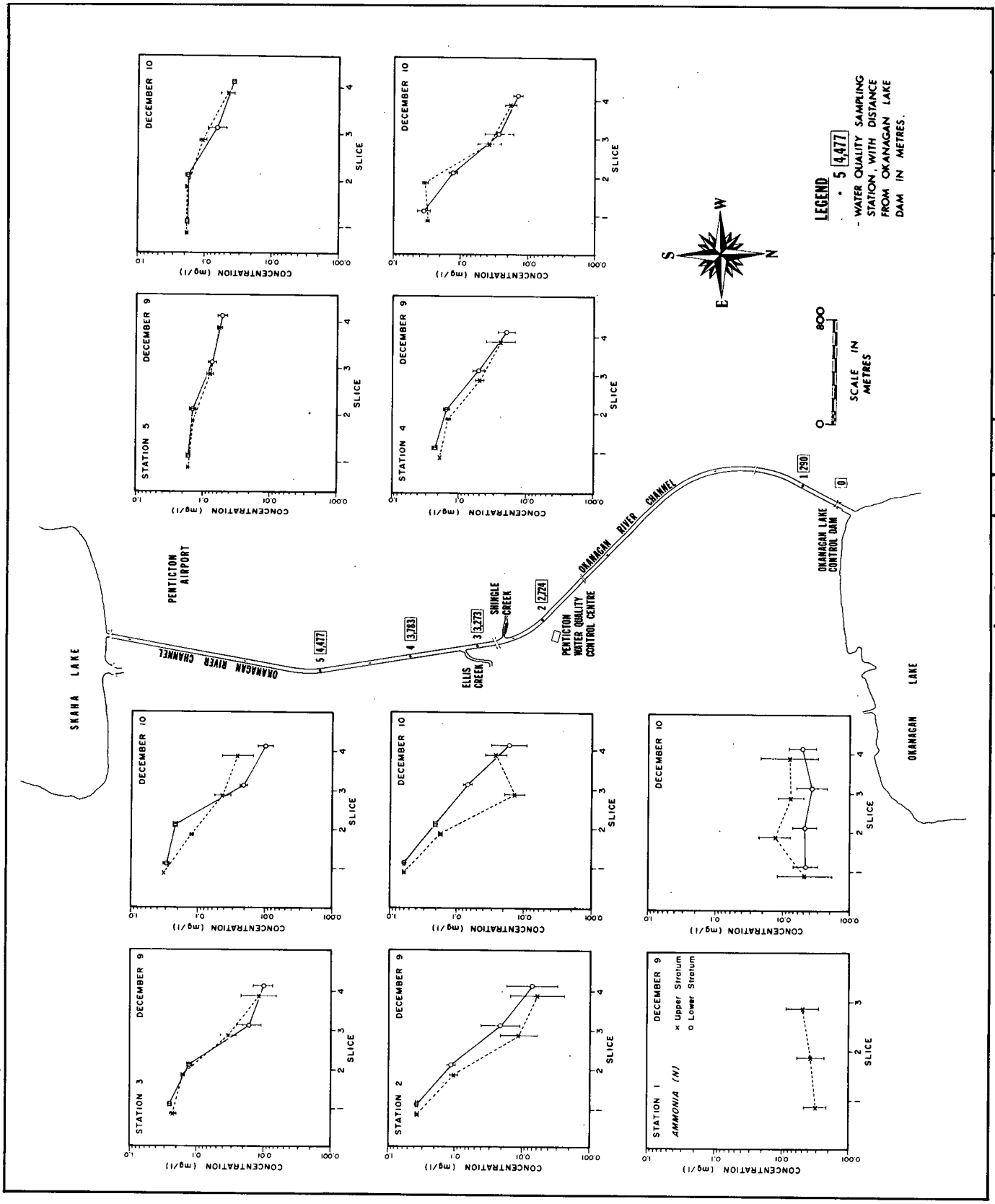



Figure 12. Longitudinal, lateral and vertical variation in concentration of ammonia, December 9 and 10, 1976. Original observations were transformed logarithmically ($\log_{10}$) and confidence intervals around geometric mean concentrations are shown on logarithmic scale.

TABLE 9

Nutrient Dispersion in the Okanagan River at Penticton, December 1976

Variation in Ammonia Loading along Investigated River Reach

Simultaneous Sampling Method

| | Station | December 9 and 10 Discharge $m^3 s^{-1}$ | Increase by Station % | Load kg $day^{-1}$ | December 9 Increase by Station % | Load kg $day^{-1}$ | December 10 Increase by Station % |
|---|---|---|---|---|---|---|---|
| 1 | Below Okanagan Lake Dam | 26.75 | | 9.94 | | 17.56 | |
| 2 | Below the Penticton municipal outfall | 26.75 (est) | 0 | 294.03 | 2,858 | 503.69 | 2,768 |
| 3 | Below Shingle Creek | 28.26 | 6 | 260.27 | -12 | 328.86 | -35 |
| 4 | Below Ellis Creek | 28.34 | 0 | 267.38 | 3 | 377.08 | 15 |
| 5 | Near the Penticton Airport | 28.67 | 1 | 270.76 | 1 | 303.46 | -20 |
| | 1 and 5 | | 7 | | 2,624 | | 1,628 |

Note: Percentages were reduced to nearest integer.

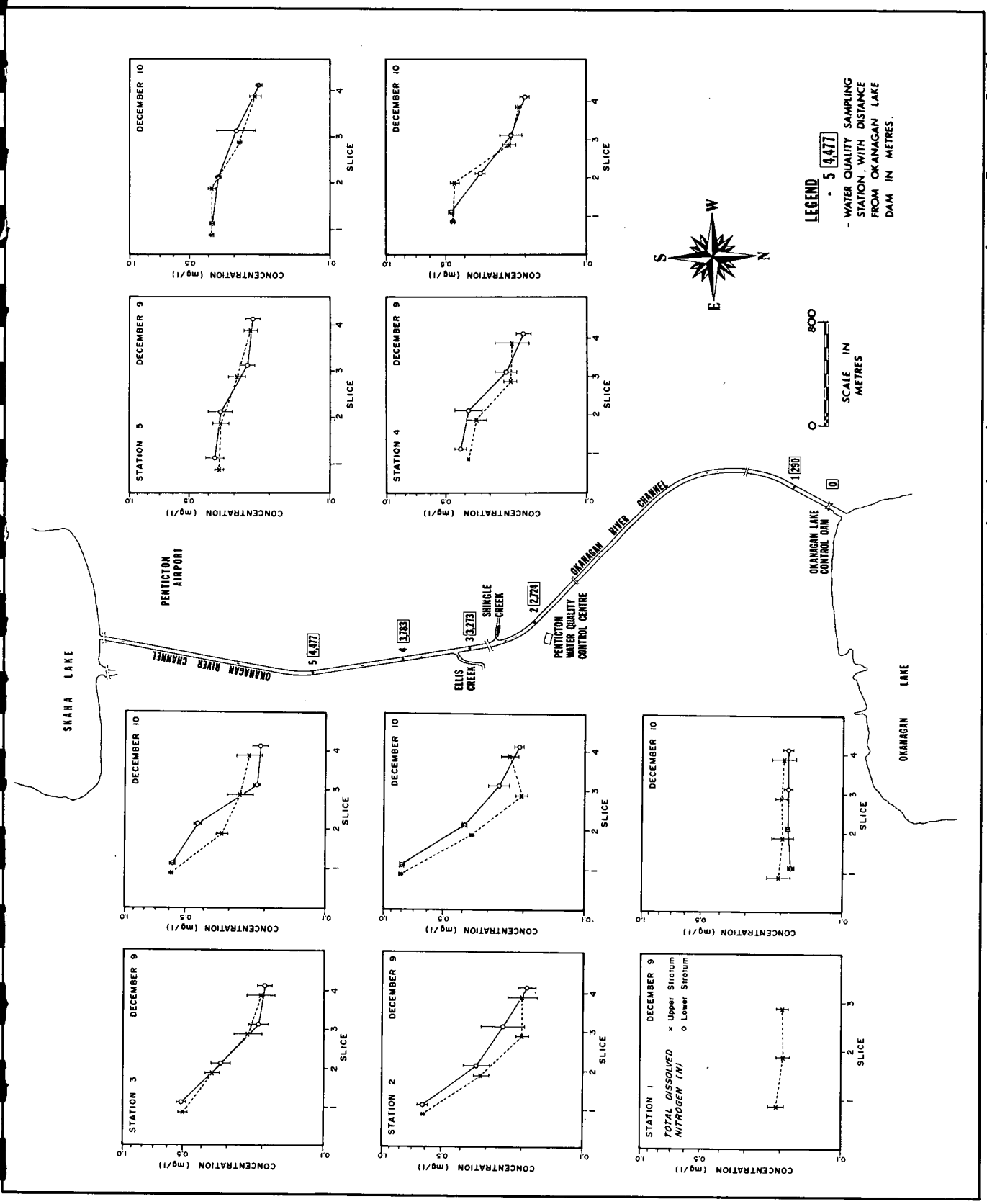



Figure 13. Longitudinal, lateral and vertical variation in concentration of total dissolved nitrogen (N), December 9 and 10, 1976. Original observations were transformed logarithmically ($\log_{10}$) and confidence intervals around geometric mean concentrations are shown on logarithmic scale.

exhibited incomplete mixing at Station 5. The 95 percent confidence limits of this nitrogen form were, generally, narrower than for ammonia.

The total dissolved nitrogen loads (Table 10) were increased at Station 2, but thereafter showed no statistically significant change. The net load increase of total dissolved nitrogen between Stations 1 and 5 during the two day period was in the range of 66 to 79 percent.

Total dissolved nitrogen includes the organic fraction which can be calculated from the difference between total nitrogen and the sum of nitrate plus nitrite and ammonia. During December 9 and 10, the organic nitrogen content calculated from loading figures at Station 5 varied in range of approximately 47 to 51 percent of the total nitrogen. This seems to be a large figure and further investigation of this nitrogen form should be investigated.

TABLE 10

Nutrient Dispersion in the Okanagan River at Pentiction, December 1976

Variation in Total Dissolved Nitrogen Loading along Investigated River Reach

Simultaneous Sampling Method

| | Station | December 9 and 10 Discharge $m^3 s^{-1}$ | December 9 and 10 Increase by Station % | December 9 Load kg $day^{-1}$ | December 9 Increase by Station % | December 10 Load kg $day^{-1}$ | December 10 Increase by Station % |
|---|---|---|---|---|---|---|---|
| 1 | Below Okanagan Lake dam | 26.75 | | 461.85 | | 445.21 | |
| 2 | Below the Penticton Municipal outfall | 26.75 (est) | 0 | 791.25 | 71 | 946.59 | 112 |
| 3 | Below Shingle Creek | 28.26 | 6 | 778.61 | -2 | 870.41 | -8 |
| 4 | Below Ellis Creek | 28.34 | 0 | 761.74 | -2 | 799.46 | -8 |
| 5 | Near the Penticton Airport | 28.67 | 1 | 768.69 | 1 | 794.70 | -1 |
| | 1 and 5 | | 7 | | 66 | | 79 |

Note: Percentages were reduced to nearest integer.

# 4. SUMMARY

The concentrations and loads of primary nutrients in the Okanagan River reach connecting Okanagan and Skaha Lakes were examined during two short-term pilot studies: (a) preliminary measurements and (b) nutrient dispersion study. The purpose of preliminary measurements was to examine temporal and spatial variation in nutrient concentration in the river reach. The aim of the nutrient dispersion study was to select a primary station for long-term monitoring of nutrient loads to Skaha Lake.

## 4.1 Preliminary Survey

In order to determine temporal variation of nutrient concentrations, samples for chemical analysis were collected during four-day intervals in July, August, September and December, 1976, at times of major changes of flow in the Okanagan River. Changes in nutrient concentrations were measured at two sampling stations. One station was located immediately below Okanagan Lake dam (Station 1) and the second station was selected near the Penticton Airport (Station 5).

### 4.1.2 Phosphorus

The variation of total phosphorus concentrations, ranging from 0.008 to 0.009 mg $\ell^{-1}$ at Station 1, was statistically not significant during the period when discharge was changed markedly. However, the increase in the mean concentration to 0.01 mg $\ell^{-1}$ of this phosphorus fraction was statistically significant further downstream, at Station 5. This increase is

ascribed to the influence of the Penticton municipal outfall, Shingle and Ellis Creeks.

Loads of total phosphorus varied from 2.4 to 30.8 and from 24.5 to 39.5 kg $day^{-1}$ at Stations 1 and 5, respectively.

The mean dissolved phosphorus concentration of 0.005 mg $\ell^{-1}$ did not vary significantly at Station 1 during the period when flow changed markedly. Its mean concentration of 0.008 mg $\ell^{-1}$ increased significantly at Station 5.

Loads of dissolved phosphorus varied from 1.6 to 11.6 kg $day^{-1}$ at Station 1 and were approximately 17 kg $day^{-1}$ at Station 5.

4.1.3 Nitrogen

The concentrations of nitrate plus nitrite exhibited highly significant monthly variations at both sampling stations. The mean concentration of this nitrogen form varied from 0.003 to 0.036 mg $\ell^{-1}$ at Station 1 and from 0.004 to 0.049 mg $\ell^{-1}$ at Station 5.

Loads of nitrate plus nitrite varied in the range from 7.4 to 137.4 and from 20.2 to 182.2 kg $day^{-1}$ at Stations 1 and 5, respectively.

The mean concentration of ammonia varied significantly from 0.009 to 0.045 mg $\ell^{-1}$ at Station 1 and from 0.038 to 0.183 at Stations 5. Loads of ammonia were ranging from 4.4 to 108.7 and 95.1 to 453.2 kg $day^{-1}$ at Stations 1 and 5.

The mean concentration of total dissolved nitrogen varied from 0.187 to 0.231 mg $\ell^{-1}$ at Station 1 and from 0.194 to 0.335 mg $\ell^{-1}$ at Station 5. Loads of total nitrogen ranged

from 61.7 to 725.3 and from 681.2 to 1,072.6 kg $day^{-1}$ at Stations 1 and 5, respectively.

4.2 Station Selection - Nutrient Dispersion Study

Nutrient dispersion study was conducted during a two-day sampling period, on December 9 and 10, 1976. Hydrometric and chemical measurements were taken at the following five stations: Station 1 (below Okanagan Lake dam); Station 2 (below the Penticton municipal outfall); Station 3 (below Shingle Creek); Station 4 (below Ellis Creek) and Station 5 (near the Penticton Airport). The locations of the stations were defined in terms of distances of the stations downstream from the Okanagan Lake dam. Statistical analysis was used to determine variation in the longitudinal dispersion of nutrient concentrations and the degree of their lateral and vertical mixing in cross-section of each station.

Discharge, regulated to remain essentially constant, was 26.75 and 28.67 $m^3$ $s^{-1}$ at Stations 1 and 5, respectively. This 7 percent increase resulted from contributions of the Penticton waste treatment plant and Shingle and Ellis Creeks.

The plot of discharge and velocity versus distance from left bank at each station indicated that the flow was asymmetrical at Stations 2, 3 and 4 and symmetrical in Stations 1 and 5.

4.2.1 Phosphorus

The concentration of total phosphorus exhibited pronounced longitudinal, lateral and vertical variations along the river reach. In the channel cross-section of Station 1,

the mean concentration of this phosphorus fraction varied from 0.007 to 0.008 mg $\ell^{-1}$. Below the outfall, the mean concentration of this constituent ranged from 0.013 to 0.014 mg $\ell^{-1}$. The cross-sectional asymmetry of flow distribution observed at stations below the outfall and the two tributary streams was accompanied by the significant lateral and vertical variation in total phosphorus concentrations. At Station 5, its cross-sectional concentration mean was in the range of 0.010 to 0.011. On December 9, 1976, there was no significant concentration difference between sampling points located in the two strata across the channel at this station.

In comparison with total phosphorus, dissolved phosphorus showed a smaller, but significant increase in concentration at the station located below the outfall. The concentration means of this constituent were 0.005 and 0.006 mg $\ell^{-1}$ in the channel cross-sections of Stations 1 and 2, respectively. Also, lateral and vertical variations of dissolved phosphorus concentrations downstream from the outfall were less pronounced than those of total phosphorus. According to analysis of variance and multiple range test, the measurements of concentrations of both phosphorus forms indicated that vertical and lateral mixing along the river reach were nearly complete at a distance of approximately 1.75 km downstream from the Penticton outfall.

Loads of total phosphorus measured during the two-day dispersion study at the station located below the Okanagan Lake dam and Station 2 were in range of 17 to 19 and 30 to 33 kg day $^{-1}$, respectively.

Prior to 1972, the contribution of the Penticton waste treatment plant of total phosphorus entering Skaha Lake was approximately 60 percent (Canada B.C. Okanagan Basin Agreement, 1974). The nutrient dispersion study indicated that the net load increase of this constituent along the full river reach was approximately 45 percent, measured as difference between Station 1 and Station 5. This finding requires verification during the long-term monitoring program.

Loads of dissolved phosphorus, measured at the station located below Okanagan Lake dam and Station 2 were 12 and 14 kg $day^{-1}$, respectively. Prior to 1972, 82 percent of ortho-phosphorus loads entering Skaha Lake were attributable to the Penticton treatment plant (op.cit.). The nutrient dispersion study indicated that the net increase of dissolved phosphorus load along the river reach was approximately 50 percent. This finding requires verification during the long-term monitoring program.

In summary, the limited data on total phosphorus loadings obtained along the Okanagan River reach support the idea that there is a small contribution of this form of phosphorus from the tributary creeks. On the other hand, dissolved phosphorus loadings indicate that the contribution of the tributaries is as great as that of the treatment plant. Urban runoff is at least in part responsible for the dissolved phosphorus contribution from Ellis Creek.

### 4.2.2 Nitrogen

The concentrations of nitrate plus nitrite showed the smallest variation of all the nitrogen forms analysed. The mean concentrations of this nitrogen form varied form 0.038 to 0.039 mg $\ell^{-1}$ and from 0.037 to 0.041 mg $\ell^{-1}$ at the channel cross-sections of Stations 1 and 2, respectively. The 95 percent confidence limits around the concentration mean of this nitrogen form were very narrow. This finding indicated that small differences in concentration of this nitrogen form, measured laterally at all stations, were statistically significant. The lateral concentration variation in the channel cross-section was evident below the tributary creeks, particularly below Ellis Creek. The mean concentrations of nitrate plus nitrite varied from 0.041 to 0.045 mg $\ell^{-1}$ and from 0.042 to 0.047 mg $\ell^{-1}$ at the channel cross-section of Stations 4 and 5, respectively. Statistical analysis indicated incomplete mixing at all stations along the river reach.

Loads of nitrate plus nitrite did not show significant increase below the outfall but below Shingle and Ellis Creeks the loads of this nitrogen form increased over the two-day study period by an average of 15 percent with respect to Station 2. There was also a continuing increase between Stations 4 and 5 which probably derives from riparian and ground water sources.

Ammonia concentration at Station 1 was very small, ranging from 0.004 to 0.008 mg $\ell^{-1}$. Below the outfall, however, its concentration increased considerably. At the cross-section of this station, the mean ammonia concentration varied from

0.127 to 0.218 mg $\ell^{-1}$, with maximum of 0.615 mg $\ell^{-1}$ observed in the slice close to the left bank. The mean concentrations of ammonia were still high at all stations located downstream. At Station 5, the mean concentration of ammonia varied from 0.11 to 0.12 mg $\ell^{-1}$. The lateral concentration gradient in the channel cross-section at this station was markedly reduced but mixing of ammonia was still incomplete. It became evident that to achieve complete mixing of this nitrogen form, overwhelmingly supplied by the effluent from the treatment plant, a considerably longer river reach would be required.

During the two-day study period, the ammonia loads varied from 10 to 18 kg $day^{-1}$ at Station 1. But below the outfall, the increased loads of ammonia ranged from 290 to 504 kg $day^{-1}$ and remained in the range of 270 to 303 kg $day^{-1}$ at Station 5. It can be concluded that much of this ammonia load reached Skaha Lake.

The concentration of total dissolved nitrogen was uniformly distributed at Station 1 and its cross-sectional mean was 0.19 mg $\ell^{-1}$. The range of mean concentrations of this constituent was from 0.34 to 0.41 mg $\ell^{-1}$ and 0.31 to 0.32 mg $\ell^{-1}$ at Stations 2 and 5, respectively. The substantial concentration gradients for this nitrogen form in the cross-sections of all stations and also its incomplete mixing at Station 5 were attributable to the high concentrations of ammonia.

The total dissolved nitrogen loads, ranging from 460 to 445 kg $day^{-1}$ at Station 1, increased to the range from 791 to

946 kg $day^{-1}$ at Station 2, but further downstream it showed no statistically significant change.

The difference between total dissolved nitrogen and the sum of nitrate plus nitrite and ammonia is accounted for by dissolved organic nitrogen. This fraction of nitrogen which contributes about 50 percent of the total dissolved nitrogen should be investigated further.

# 5. CONCLUSIONS AND RECOMMENDATIONS

## Accuracy and Precision

The pilot studies conducted on the Okanagan River reach connecting Okanagan and Skaha Lakes show significant temporal and spatial variability in nutrient concentrations. Individual point samples cannot provide a reliable indication of nutrient flux. Calculation of a few daily nutrient loadings during widely varying discharges indicate that major changes in flow can produce large changes in nutrient flux. However, to turn to a concentration - discharge relationship approach to nutrient loading determination is not feasible because of the regulation of flow by the Okanagan Lake dam and variable nutrient concentrations from the municipal outfall.

During the long-term nutrient monitoring project, at selected stations, a function that relates the concentration gradients in the channel cross-sections to discharge should be developed. The concentration measurements at two points on such a gradient, particularly at the station near the airport, could provide the data for precise loading determination to Skaha Lake. These two-point measurements in the cross-section should be continued with appropriate frequency and a measure of precision of nutrient loadings developed. Adequate supplementary measurements of vertical and horizontal concentration gradients should be made at more points in the channel cross-section. Then the two-point measurements will be used as indicators of nutrient concentrations and their cross-sectional gradient patterns.

## Selection of Nutrient Monitoring Stations

### Okanagan River at Penticton

Based on the nutrient dispersion study the selected stations for long-term nutrient monitoring program on the Okanagan River reach at Penticton are (a) below the Okanagan Lake dam and (b) near the airport.

The measurements obtained at the station located immediately below the Okanagan Lake dam can provide information on nutrient fluxes from the lake, useful for comparison with the measurement of nutrient loads coming from the Penticton municipal outfall. On a long-term basis, the nutrient output from the lake can indicate the effect of remedial actions undertaken to reduce nutrient loads to Okanagan Lake.

The dispersion study indicated that nutrient loadings carried by the Okanagan River to Skaha Lake can be adequately assessed by measurements at the station selected near the airport. The station near the Penticton Airport should be equipped with a manual staff guage to be read daily so that some evidence is available of large water withdrawals or of extreme backwater effects. Instantaneous discharge measurements should be made at this station periodically.

### Tributaries to Okanagan River

Pilot studies indicate that non-point sources of nutrients make a greater contribution than point sources as far as phosphorus loadings to Skaha Lake are concerned. Although, there is a small contribution of total phosphorus

from tributary creeks to Okanagan River at Penticton, data on dissolved phosphorus suggest that the contribution of the tributaries to the loading of this phosphorus fraction can be as great as that from the treatment plant.

## Additional Recommendations

### Phosphorus

Phosphorus associated with sediment should be monitored because it was indicated by the nutrient dispersion study that some deposition of particulates on the stream bed above the station near the airport could be expected. Suspended sediment loads should be established.

### Ammonia

Ammonia from the Penticton waste treatment plant is entering Skaha Lake at what may be critical levels. Representative measurements, based on those made during the two-day nutrient dispersion study, should be made at appropriate intervals over a two year period to ensure that adequate seasonal or annual loadings and their trends can be assessed.

### Organic Nitrogen

Organic nitrogen content appears to be a significant portion of total nitrogen loads and should be further investigated. Finally, the evaluation of the relative importance of nutrient derived from diverse sources, both point and non-point sources, should be given high priority in water resource management planning in the Okanagan Valley.

# 6. REFERENCES

Afghan, B.K. P.D. Goulden, and J.F. Ryan, 1970. An Automated Method for Determination of Soluble Nitrogen in Natural Waters. Advances in Automated Analysis. Presented at the Technicon International Congress, November 2-4, in New York, New York, pp. 291-297.

Canada-British Columbia Okanagan Basin Agreement, 1974. Technical Supplement III to the Final Report. Water Quantity Alternatives & Supporting Water Quantity Data. Published by Office of the Study Director, Box 458, Penticton, B.C., pp. 1-565.

Canada-British Columbia Okanagan Basin Agreement, 1974. The Limnology of the Major Okanagan Basin Lakes. Technical Supplement V, to the Final Report, Published by Office of the Study Director, Box 458, Penticton, B.C. pp. 1-161.

Canada-British Columbia Okanagan Basin Agreement, 1974. Summary Report of the Consultative Board including the Comprehensive Framework Plan, pp. 1-40.

Erlebach, W.E., 1975. Trends in Water Quality Monitoring, Proceedings of the Canadian Hydrology Symposium-75. Winnipeg, August, pp. 606-613.

Fleming W.M. and J.G. Stockner, 1975. Predicting the impacts of phosphorus management policies on the entrophication of Skaha Lake, British Columbia. In: Verh. int. Ver. Limnol., Stuttgart, October, Vol. 19, pp. 241-248.

Gale, R.M., and A. Demayo, 1975. Water Quality Data Collection Programs Environment Canada, pp. 8-20. In: Water Resources Instrumentation. Volume 2 Data Acquisition and Analysis. Proceedings of the International Seminar and Exposition on Water Resources Instrumentation held June 4-6, 1974 in Chicago, Illinois, pp. 1-593.

Gburek, W.J. and Walter R. Heald, 1974. Soluble Phosphate Output of an Agricultural Watershed in Pennsylvania. Water Resources Research. Vol. 10, No. 1, pp. 113-118.

P. Kleiber and W.E. Erlebach, 1976. Limitations of Single Water Samples in Representing Mean Water Quality, III. Effect of Variability in Concentration Measurements on Estimates of Nutrient Loadings in the Squamish River, B.C. Water Quality Branch Inland Waters Directorate Pacific and Yukon Region, Vancouver, B.C., pp. 1-11.

Leopold L.B., M.G. Wolman and J.P. Miller, 1964. Fluvial Processes in Geomorphology. W.H. Freeman and Company. San Francisco and London, pp. 1-522.

Likens, G.T., 1972. Eutrohpication and Aquatic Ecosystems, pp. 3-13. In: Nutrients and Eutrophication. The Limiting-Nutrient Controversy. Proceedings of the Symposium on Nutrients and Eutrophication. The Limiting-Nutrient Controversy. Vol. 1, American Society of Limnology and Oceanography, Inc., Allen Press, Inc. Lawrence, Kansas.

Miller, R.G., 1966. Simultaneous Statistical Inference, McGraw-Hill, Inc., New York, pp. 1-272.

Mah, R, 1976. Precision and Accuracy in the Chemical Analyses of Water Samples - Analytical Services Division, Water Quality Branch, Pacific and Yukon Region. (Internal Document).

Murphy, J. and J.P. Riley, 1962. A Modified Single Solution Method for the Determination of Phosphate in Natural Waters. Anal. Chim. Acta. Vol. 27, pp. 31-36.

Oguss, E. and W.E. Erlebach, 1976. Limitations of Single Water Samples in Representing Mean Water Quality. I. Thompson River at Shaw Spring, British Columbia, Technical Bulletin No. 95. Inland Waters Directorate, Pacific and Yukon Region. Water Quality Branch, Vancouver, B.C., pp. 1-22.

Ozga, W.J., 1971. Manual of Hydrometric Office Procedure, Department of Fisheries and Forestry, Inland Waters Branch, Water Survey of Canada, 3rd Ed., pp. 1-38.

Patalas, K. and A. Salki, 1973. Crustacean Plankton and the Eutrophication of Lakes in the Okanagan Valley, B.C. J. Fish, Res. Bd. of Canada 30: 519-542.

Sayre, W.W., 1973. Natural Mixing Processes in Rivers. Chapter 6 in H.W. Shen (ed.) Environmental Impact on Rivers, Fort Collins, Colorado, pp. 601-637.

Scheffé, H., 1959. The Analysis of Variance. John Lindon & Sons, Inc., New York, pp. 465.

Stockner, J.G. and T.G. Northcote, 1974. Recent Limnological Studies of Okanagan Basin Lakes and their Contribution to Comprehensive Water Resource Planning. Journal Fisheries Research Board of Canada, Vol. 31, No. 5., pp. 955-975.

Taylor, A.W., W.M. Edwards, and E.C. Simpson, 1971. Nutrients in Streams Draining Woodland and Farmland near Coshocton, Ohio, Water Resour. Res., 7(1), pp. 81-89.

Technicon Instruments Corporation, 1971. Ammonia in Water and Sea Water. Industrial Method No. 154-71 W. Technicon AutoAnalyzer II Methodology.

Technicon Instruments Corporation, 1972. Nitrate Plus Nitrite in Water and Sea Water, Industrial Method No. 158-71W. Technicon AutoAnalyzer II Methodology.

Vollenweider, R.A., 1968. The Scientific Basis of Lake and Stream Eutrophication, with Particular Reference to Phosphorus and Nitrogen as Eutrophication Factors. Tech. Rep. OECD, Paris, DAS/CSI/68, 27:1-182.

Vollenweider, R.A., 1971. Scientific Fundamentals of the Eutrophication of Lakes and Flowing Waters With Particular Reference to Nitrogen and Phosphorus as Factors in Eutrophication. OECD. Paris. pp. 1-159. Annex with Bibliography 1-61.

# APPENDIX I

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF TOTAL PHOSPHORUS(P) CONCENTRATION(MG/L)

STATION 01

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 2 | 0.35556E-05 | 0.17778E-05 | 1.6000 | 0.27739 |
| ERROR | 6 | 0.66667E-05 | 0.11111E-05 | | |
| TOTAL | 8 | 0.10222E-04 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | CROSS-SECTION |
|---|---|---|---|---|
| UPPER STRATUM | 0.0070 | 0.0083 | 0.0070 | 0.0074 |
| | 0.0000 | 0.0015 | 0.0010 | 0.0011 |

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 |
|---|---|---|---|
| GROUP 01 | ---------- | | |

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.20500E-04 | 0.68333E-05 | 0.57343 | 0.64066 |
| STRATM | 1 | 0.81667E-05 | 0.81667E-05 | 0.68532 | 0.41994 |
| SL *ST | 3 | 0.88500E-04 | 0.29500E-04 | 2.4755 | 0.98741E-01 |
| ERROR | 16 | 0.19067E-03 | 0.11917E-04 | | |
| TOTAL | 23 | 0.30783E-03 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0107 | 0.0067 | 0.0120 | 0.0067 | 0.0090 | 0.0084 |
| | 0.0025 | 0.0012 | 0.0061 | 0.0012 | 0.0038 | 0.0037 |
| LOWER STRATUM | 0.0070 | 0.0070 | 0.0063 | 0.0110 | 0.0078 | |
| | 0.0010 | 0.0000 | 0.0006 | 0.0069 | 0.0036 | |
| SLICE | 0.0088 | 0.0068 | 0.0092 | 0.0088 | | |
| | 0.0026 | 0.0007 | 0.0050 | 0.0050 | | |

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ---------- | | | |

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF TOTAL PHOSPHORUS(P) CONCENTRATION(MG/L)

STATION 02

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.29300E-03 | 0.97667E-04 | 7.3250 | 0.26206E-02 |
| STRATM | 1 | 0.10667E-04 | 0.10667E-04 | 0.80000 | 0.38435 |
| SL *ST | 3 | 0.34333E-04 | 0.11444E-04 | 0.85833 | 0.48266 |
| ERROR | 16 | 0.21333E-03 | 0.13333E-04 | | |
| TOTAL | 23 | 0.55133E-03 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0190 | 0.0127 | 0.0087 | 0.0083 | 0.0122 | 0.0128 |
| | 0.0017 | 0.0025 | 0.0006 | 0.0015 | 0.0047 | 0.0049 |
| LOWER STRATUM | 0.0173 | 0.0140 | 0.0137 | 0.0090 | 0.0135 | |
| | 0.0015 | 0.0044 | 0.0081 | 0.0026 | 0.0052 | |
| SLICE | 0.0182 | 0.0133 | 0.0112 | 0.0086 | | |
| | 0.0017 | 0.0033 | 0.0058 | 0.0020 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

4.046

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ---------- | | | |
| GROUP 02 | | ---------- | | |

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.79546E-03 | 0.26515E-03 | 93.583 | 0.23266E-09 |
| STRATM | 1 | 0.45375E-04 | 0.45375E-04 | 16.015 | 0.10280E-02 |
| SL *ST | 3 | 0.10746E-03 | 0.35819E-04 | 12.642 | 0.17200E-03 |
| ERROR | 16 | 0.45333E-04 | 0.28333E-05 | | |
| TOTAL | 23 | 0.99362E-03 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0273 | 0.0093 | 0.0127 | 0.0137 | 0.0158 | 0.0144 |
| | 0.0012 | 0.0015 | 0.0012 | 0.0015 | 0.0073 | 0.0066 |
| LOWER STRATUM | 0.0213 | 0.0137 | 0.0093 | 0.0077 | 0.0130 | |
| | 0.0032 | 0.0006 | 0.0015 | 0.0015 | 0.0058 | |
| SLICE | 0.0243 | 0.0115 | 0.0110 | 0.0107 | | |
| | 0.0039 | 0.0026 | 0.0022 | 0.0036 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

4.046

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ------ | | | |
| GROUP 02 | | ---------- | | |

SLICE X STRATUM INTERACTION

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN ELEMENTS

4.897

GROUPS OF MEANS

| ELEMENT | 1 | 2 | 4 | 7 | 5 | 3 | 6 | 8 |
|---|---|---|---|---|---|---|---|---|
| GROUP 01 | ------ | | | | | | | |
| GROUP 02 | | ------ | | | | | | |
| GROUP 03 | | | ---------- | | | | | |
| GROUP 04 | | | | | | ---------- | | |

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF TOTAL PHOSPHORUS(P) CONCENTRATION(MG/L)

STATION 03

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.17833E-03 | 0.59444E-04 | 67.937 | 0.25445E-08 |
| STRATM | 1 | 0.41667E-05 | 0.41667E-05 | 4.7619 | 0.44351E-01 |
| SL *ST | 3 | 0.16833E-04 | 0.56111E-05 | 6.4127 | 0.46546E-02 |
| ERROR | 16 | 0.14000E-04 | 0.87500E-06 | | |
| TOTAL | 23 | 0.21333E-03 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0157 | 0.0093 | 0.0070 | 0.0070 | 0.0098 | 0.0093 |
| | 0.0006 | 0.0015 | 0.0000 | 0.0000 | 0.0038 | 0.0030 |
| LOWER STRATUM | 0.0120 | 0.0090 | 0.0077 | 0.0070 | 0.0089 | |
| | 0.0010 | 0.0010 | 0.0012 | 0.0010 | 0.0022 | |
| SLICE | 0.0138 | 0.0092 | 0.0073 | 0.0070 | | |
| | 0.0021 | 0.0012 | 0.0008 | 0.0006 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

4.046

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ------ | | | |
| GROUP 02 | | ------ | | |
| GROUP 03 | | | ---------- | |

SLICE X STRATUM INTERACTION

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN ELEMENTS

4.897

GROUPS OF MEANS

| ELEMENT | 1 | 2 | 3 | 4 | 6 | 8 | 5 | 7 |
|---|---|---|---|---|---|---|---|---|
| GROUP 01 | ------ | | | | | | | |
| GROUP 02 | | ------ | | | | | | |
| GROUP 03 | | | ---------- | | | | | |

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.56317E-03 | 0.18772E-03 | 16.937 | 0.32037E-04 |
| STRATM | 1 | 0.13500E-04 | 0.13500E-04 | 1.2180 | 0.28607 |
| SL *ST | 3 | 0.18333E-05 | 0.61111E-06 | 0.55138E-01 | 0.98234 |
| ERROR | 16 | 0.17733E-03 | 0.11083E-04 | | |
| TOTAL | 23 | 0.75583E-03 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0220 | 0.0140 | 0.0090 | 0.0103 | 0.0138 | 0.0131 |
| | 0.0020 | 0.0009 | 0.0026 | 0.0049 | 0.0059 | 0.0057 |
| LOWER STRATUM | 0.0200 | 0.0120 | 0.0083 | 0.0090 | 0.0123 | |
| | 0.0061 | 0.0010 | 0.0015 | 0.0035 | 0.0057 | |
| SLICE | 0.0210 | 0.0130 | 0.0087 | 0.0097 | | |
| | 0.0042 | 0.0014 | 0.0020 | 0.0039 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

4.046

GROUPS OF MEANS

| SLICE | 1 | 2 | 4 | 3 |
|---|---|---|---|---|
| GROUP 01 | ------ | | | |
| GROUP 02 | | ---------- | | |

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF TOTAL PHOSPHORUS(P) CONCENTRATION(MG/L)

STATION 04

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.11046E-03 | 0.36819E-04 | 10.157 | 0.54900E-03 |
| STRATM | 1 | 0.20417E-05 | 0.20417E-05 | 0.56322 | 0.46386 |
| SL *ST | 3 | 0.17458E-04 | 0.58194E-05 | 1.6054 | 0.22743 |
| ERROR | 16 | 0.58000E-04 | 0.36250E-05 | | |
| TOTAL | 23 | 0.18796E-03 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0120 | 0.0103 | 0.0077 | 0.0070 | 0.0093 | 0.0095 |
| | 0.0010 | 0.0006 | 0.0015 | 0.0010 | 0.0023 | 0.0029 |
| LOWER STRATUM | 0.0107 | 0.0137 | 0.0077 | 0.0073 | 0.0098 | |
| | 0.0015 | 0.0038 | 0.0015 | 0.0023 | 0.0034 | |
| SLICE | 0.0113 | 0.0120 | 0.0077 | 0.0072 | | |
| | 0.0014 | 0.0030 | 0.0014 | 0.0016 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE
FOR TUKEY'S TEST
ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

4.046

GROUPS OF MEANS
SLICE 2 1 3 4
GROUP 01 ----------
GROUP 02 ----------

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.20900E-03 | 0.69667E-04 | 1.3671 | 0.28854 |
| STRATM | 1 | 0.26667E-05 | 0.26667E-05 | 0.52330E-01 | 0.82196 |
| SL *ST | 3 | 0.39033E-03 | 0.13011E-03 | 2.5533 | 0.91923E-01 |
| ERROR | 16 | 0.81533E-03 | 0.50958E-04 | | |
| TOTAL | 23 | 0.14173E-02 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0207 | 0.0180 | 0.0083 | 0.0070 | 0.0135 | 0.0132 |
| | 0.0115 | 0.0062 | 0.0006 | 0.0010 | 0.0084 | 0.0079 |
| LOWER STRATUM | 0.0120 | 0.0103 | 0.0193 | 0.0097 | 0.0128 | |
| | 0.0062 | 0.0006 | 0.0138 | 0.0021 | 0.0077 | |
| SLICE | 0.0163 | 0.0142 | 0.0138 | 0.0833 | | |
| | 0.0096 | 0.0058 | 0.0106 | 0.0021 | | |

GROUPS OF MEANS
SLICE 1 2 3 4
GROUP 01 ----------

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF TOTAL PHOSPHORUS(P) CONCENTRATION(MG/L)

STATION 05

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.37458E-04 | 0.12486E-04 | 4.4069 | 0.19302E-01 |
| STRATM | 1 | 0.22042E-04 | 0.22042E-04 | 7.7794 | 0.13132E-01 |
| SL *ST | 3 | 0.57917E-05 | 0.19306E-05 | 0.68137 | 0.57621 |
| ERROR | 16 | 0.45333E-04 | 0.28333E-05 | | |
| TOTAL | 23 | 0.11062E-03 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0113 | 0.0090 | 0.0080 | 0.0083 | 0.0092 | 0.0101 |
| | 0.0015 | 0.0000 | 0.0000 | 0.0015 | 0.0016 | 0.0022 |
| LOWER STRATUM | 0.0123 | 0.0123 | 0.0090 | 0.0107 | 0.0111 | |
| | 0.0006 | 0.0040 | 0.0010 | 0.0006 | 0.0023 | |
| SLICE | 0.0118 | 0.0107 | 0.0085 | 0.0095 | | |
| | 0.0012 | 0.0031 | 0.0008 | 0.0016 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE
FOR TUKEY'S TEST
ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

4.046

GROUPS OF MEANS

| SLICE | 1 | 2 | 4 | 3 |
|---|---|---|---|---|
| GROUP 01 | ---------- | ---------- | | |
| GROUP 02 | | ---------- | ---------- | |

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.20833E-04 | 0.69444E-05 | 2.4876 | 0.97650E-01 |
| STRATM | 1 | 0.0 | 0.0 | 0.0 | 1.0000 |
| SL *ST | 3 | 0.15000E-04 | 0.50000E-05 | 1.7910 | 0.18940 |
| ERROR | 16 | 0.44667E-04 | 0.27917E-05 | | |
| TOTAL | 23 | 0.80500E-04 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0123 | 0.0120 | 0.0120 | 0.0087 | 0.0011 | 0.0113 |
| | 0.0015 | 0.0000 | 0.0017 | 0.0025 | 0.0021 | 0.0019 |
| LOWER STRATUM | 0.0117 | 0.0123 | 0.0100 | 0.0110 | 0.0013 | |
| | 0.0015 | 0.0012 | 0.0000 | 0.0026 | 0.0017 | |
| SLICE | 0.0120 | 0.0122 | 0.0110 | 0.0098 | | |
| | 0.0014 | 0.0008 | 0.0015 | 0.0026 | | |

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ---------- | ---------- | ---------- | |

# APPENDIX II

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF DISSOLVED PHOSPHORUS(P) CONCENTRATION(MG/L)

STATION 01

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.27917E-05 | 0.93055E-06 | 1.0635 | 0.39217 |
| STRATM | 1 | 0.20417E-05 | 0.20417E-05 | 2.3333 | 0.14616 |
| SL *ST | 3 | 0.12500E-06 | 0.41667E-07 | 0.47619E-01 | 0.98572 |
| ERROR | 16 | 0.14000E-04 | 0.87500E-06 | | |
| TOTAL | 23 | 0.18958E-04 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0057 | 0.0047 | 0.0053 | 0.0057 | 0.0053 | 0.0050 |
| | 0.0012 | 0.0006 | 0.0015 | 0.0012 | 0.0012 | 0.0009 |
| LOWER STRATUM | 0.0050 | 0.0043 | 0.0047 | 0.0050 | 0.0048 | |
| | 0.0010 | 0.0006 | 0.0006 | 0.0000 | 0.0006 | |
| SLICE | 0.0053 | 0.0045 | 0.0050 | 0.0053 | | |
| | 0.0010 | 0.0005 | 0.0011 | 0.0008 | | |

GROUPS OF MEANS

| SLICE 01 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ---------- | | | |

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF DISSOLVED PHOSPHORUS(P) CONCENTRATION(MG/L)

STATION 02

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.23458E-04 | 0.78195E-05 | 3.8299 | 0.30494E-01 |
| STRATM | 1 | 0.37500E-06 | 0.37500E-06 | 0.18367 | 0.67395 |
| SL *ST | 3 | 0.17458E-04 | 0.58194E-05 | 2.8503 | 0.70268E-01 |
| ERROR | 16 | 0.32667E-04 | 0.20417E-05 | | |
| TOTAL | 23 | 0.73958E-04 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0063 | 0.0060 | 0.0060 | 0.0060 | 0.0061 | 0.0062 |
| | 0.0035 | 0.0010 | 0.0010 | 0.0010 | 0.0061 | 0.0018 |
| LOWER STRATUM | 0.0093 | 0.0063 | 0.0050 | 0.0047 | 0.0063 | |
| | 0.0006 | 0.0006 | 0.0000 | 0.0006 | 0.0063 | |
| SLICE | 0.0078 | 0.0062 | 0.0055 | 0.0053 | | |
| | 0.0028 | 0.0008 | 0.0008 | 0.0010 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE
FOR TUKEY'S TEST
ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

4.046

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ---------- | | | |
| GROUP 02 | | ---------- | | |

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF DISSOLVED PHOSPHORUS(P) CONCENTRATION(MG/L)

STATION 03

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.52125E-04 | 0.17375E-04 | 9.9286 | 0.61626E-03 |
| STRATM | 1 | 0.37500E-06 | 0.37500E-06 | 0.21429 | 0.64966 |
| SL *ST | 3 | 0.41250E-05 | 0.13750E-05 | 0.78571 | 0.51924 |
| ERROR | 16 | 0.28000E-04 | 0.17500E-05 | | |
| TOTAL | 23 | 0.84625E-04 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0097 | 0.0077 | 0.0050 | 0.0057 | 0.0070 | 0.0069 |
| | 0.0006 | 0.0021 | 0.0000 | 0.0006 | 0.0021 | 0.0019 |
| LOWER STRATUM | 0.0083 | 0.0073 | 0.0060 | 0.0053 | 0.0068 | |
| | 0.0006 | 0.0012 | 0.0026 | 0.0006 | 0.0018 | |
| SLICE | 0.0090 | 0.0075 | 0.0055 | 0.0055 | | |
| | 0.0009 | 0.0015 | 0.0018 | 0.0005 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE
FOR TUKEY'S TEST
ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

4.046

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ---------- | | | |
| GROUP 02 | | ---------- | | |

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF DISSOLVED PHOSPHORUS(P) CONCENTRATION(MG/L)

STATION 04

DECEMBER 10, 1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.45833E-06 | 0.15278E-06 | 0.62147E-01 | 0.97903 |
| STRATM | 1 | 0.41667E-07 | 0.41667E-07 | 0.16949E-01 | 0.89804 |
| SL *ST | 3 | 0.32792E-04 | 0.10931E-04 | 4.4463 | 0.18724E-01 |
| ERROR | 16 | 0.39333E-04 | 0.24583E-05 | | |
| TOTAL | 23 | 0.72625E-04 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0073 | 0.0080 | 0.0080 | 0.0050 | 0.0071 | 0.0071 |
| | 0.0015 | 0.0010 | 0.0017 | 0.0000 | 0.0017 | 0.0018 |
| LOWER STRATUM | 0.0070 | 0.0067 | 0.0060 | 0.0090 | 0.0072 | |
| | 0.0000 | 0.0006 | 0.0010 | 0.0035 | 0.0019 | |
| SLICE | 0.0072 | 0.0073 | 0.0070 | 0.0070 | | |
| | 0.0010 | 0.0010 | 0.0017 | 0.0031 | | |

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ---------- | | | |

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF DISSOLVED PHOSPHORUS(P) CONCENTRATION(MG/L)

STATION 05

DECEMBER 10, 1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.76667E-05 | 0.25556E-05 | 0.90196 | 0.46187 |
| STRATM | 1 | 0.41667E-05 | 0.41667E-05 | 1.4706 | 0.24286 |
| SL *ST | 3 | 0.28333E-05 | 0.94444E-06 | 0.33333 | 0.80140 |
| ERROR | 16 | 0.45333E-04 | 0.28333E-05 | | |
| TOTAL | 23 | 0.60000E-04 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0070 | 0.0070 | 0.0067 | 0.0057 | 0.0066 | 0.0070 |
| | 0.0000 | 0.0000 | 0.0015 | 0.0006 | 0.0009 | 0.0016 |
| LOWER STRATUM | 0.0073 | 0.0087 | 0.0067 | 0.0070 | 0.0074 | |
| | 0.0006 | 0.0021 | 0.0029 | 0.0026 | 0.0021 | |
| SLICE | 0.0072 | 0.0078 | 0.0067 | 0.0063 | | |
| | 0.0004 | 0.0016 | 0.0021 | 0.0019 | | |

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ---------- | | | |

# APPENDIX III

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF NITRATE PLUS NITRITE(N) CONCENTRATION(MG/L)

STATION 01

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 2 | 0.27444E-04 | 0.13722E-04 | 21.667 | 0.37697E-04 |
| ERROR | 15 | 0.95000E-05 | 0.63333E-06 | | |
| TOTAL | 17 | 0.36944E-04 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | CROSS-SECTION |
|---|---|---|---|---|
| UPPER STRATUM | 0.0397 | 0.0378 | 0.0367 | 0.0381 |
| | 0.0005 | 0.0007 | 0.0010 | 0.0147 |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 |
|---|---|---|---|
| GROUP 01 | ---- | | |
| GROUP 02 | | ---------- | |

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.37292E-05 | 0.12431E-05 | 6.3475 | 0.12690E-02 |
| STRATM | 1 | 0.20833E-07 | 0.20833E-07 | 0.10638 | 0.74600 |
| SL *ST | 3 | 0.39583E-06 | 0.13194E-06 | 0.67376 | 0.57321 |
| ERROR | 40 | 0.78333E-05 | 0.19583E-06 | | |
| TOTAL | 47 | 0.11979E-04 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0402 | 0.0397 | 0.0400 | 0.0395 | 0.0398 | 0.0399 |
| | 0.0004 | 0.0005 | 0.0006 | 0.0005 | 0.0006 | 0.0005 |
| LOWER STRATUM | 0.0402 | 0.0400 | 0.0400 | 0.0393 | 0.0399 | |
| | 0.0004 | 0.0000 | 0.0000 | 0.0005 | 0.0004 | |
| SLICE | 0.0402 | 0.0398 | 0.0400 | 0.0394 | | |
| | 0.0004 | 0.0004 | 0.0004 | 0.0005 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 3 | 2 | 4 |
|---|---|---|---|---|
| GROUP 01 | ---------- | | | |
| GROUP 02 | | | ---------- | |

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF NITRATE PLUS NITRITE(N) CONCENTRATION(MG/L)

STATION 02

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.82396E-04 | 0.27465E-04 | 11.268 | 0.17095E-04 |
| STRATM | 1 | 0.18750E-06 | 0.18750E-06 | 0.769239E-01 | 0.78294 |
| SL *ST | 3 | 0.11396E-04 | 0.37986E-05 | 1.5584 | 0.21446 |
| ERROR | 40 | 0.97500E-04 | 0.24375E-05 | | |
| TOTAL | 47 | 0.19148E-03 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0392 | 0.0377 | 0.0382 | 0.0362 | 0.0378 | 0.0377 |
| | 0.0020 | 0.0010 | 0.0004 | 0.0022 | 0.0019 | 0.0020 |
| LOWER STRATUM | 0.0383 | 0.0385 | 0.0390 | 0.0348 | 0.0377 | |
| | 0.0026 | 0.0005 | 0.0013 | 0.0008 | 0.0022 | |
| SLICE | 0.0387 | 0.0381 | 0.0386 | 0.0355 | | |
| | 0.0023 | 0.0009 | 0.0009 | 0.0017 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 3 | 2 | 4 |
|---|---|---|---|---|
| GROUP 01 | ---------- | ---------- | | |
| GROUP 02 | | | | ------ |

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.21635E-02 | 0.72117E-03 | 515.12 | 0.62233E-31 |
| STRATM | 1 | 0.13333E-05 | 0.13333E-05 | 0.95238 | 0.33498 |
| SL *ST | 3 | 0.54833E-04 | 0.18278E-04 | 13.056 | 0.43524E-05 |
| ERROR | 40 | 0.56000E-04 | 0.14000E-05 | | |
| TOTAL | 47 | 0.22757E-02 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0547 | 0.0378 | 0.0360 | 0.0365 | 0.0413 | 0.0411 |
| | 0.0014 | 0.0004 | 0.0006 | 0.0005 | 0.0079 | 0.0069 |
| LOWER STRATUM | 0.0507 | 0.0383 | 0.0368 | 0.0378 | 0.0409 | |
| | 0.0010 | 0.0005 | 0.0004 | 0.0026 | 0.0059 | |
| SLICE | 0.0527 | 0.0381 | 0.0364 | 0.0372 | | |
| | 0.0024 | 0.0005 | 0.0007 | 0.0019 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 4 | 3 |
|---|---|---|---|---|
| GROUP 01 | ------ | | | |
| GROUP 02 | | ---------- | | |
| GROUP 03 | | | ---------- | |

SLICE X STRATUM INTERACTION

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN ELEMENTS

4.521

GROUPS OF MEANS

| ELEMENT | 1 | 2 | 4 | 3 | 8 | 6 | 7 | 5 |
|---|---|---|---|---|---|---|---|---|
| GROUP 01 | ------ | | | | | | | |
| GROUP 02 | | ------ | | | | | | |
| GROUP 03 | | | ---------- | ---------- | ---------- | ---------- | | |
| GROUP 04 | | | | | ---------- | ---------- | ---------- | ---------- |

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF NITRATE PLUS NITRITE(N) CONCENTRATION(MG/L)

STATION 03

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.24917E-04 | 0.83056E-05 | 3.7753 | 0.17789E-01 |
| STRATM | 1 | 0.13333E-05 | 0.13333E-05 | 0.60606 | 0.44086 |
| SL *ST | 3 | 0.16667E-05 | 0.55556E-06 | 0.25253 | 0.85907 |
| ERROR | 40 | 0.88000E-04 | 0.22000E-05 | | |
| TOTAL | 47 | 0.11592E-03 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0400 | 0.0383 | 0.0383 | 0.0378 | 0.0386 | 0.0385 |
| | 0.0032 | 0.0010 | 0.0005 | 0.0008 | 0.0018 | 0.0016 |
| LOWER STRATUM | 0.0392 | 0.0385 | 0.0382 | 0.0373 | 0.0383 | |
| | 0.0020 | 0.0008 | 0.0008 | 0.0005 | 0.0013 | |
| SLICE | 0.0396 | 0.0384 | 0.0383 | 0.0376 | | |
| | 0.0026 | 0.0009 | 0.0006 | 0.0007 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ---------- | | | |
| GROUP 02 | | ---------- | | |

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.25913E-02 | 0.86378E-03 | 122.23 | 0.16653E-15 |
| STRATM | 1 | 0.0 | 0.0 | 0.0 | 1.0000 |
| SL *ST | 3 | 0.22667E-04 | 0.75556E-05 | 1.0692 | 0.37299 |
| ERROR | 40 | 0.28267E-03 | 0.70667E-05 | | |
| TOTAL | 47 | 0.28967E-02 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0565 | 0.0403 | 0.0405 | 0.0400 | 0.0443 | 0.0443 |
| | 0.0037 | 0.0014 | 0.0010 | 0.0009 | 0.0074 | 0.0078 |
| LOWER STRATUM | 0.0575 | 0.0420 | 0.0395 | 0.0383 | 0.0443 | |
| | 0.0062 | 0.0006 | 0.0005 | 0.0008 | 0.0084 | |
| SLICE | 0.0570 | 0.0412 | 0.0400 | 0.0392 | | |
| | 0.0049 | 0.0013 | 0.0009 | 0.0012 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ------ | | | |
| GROUP 02 | | ---------- | | |

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF NITRATE PLUS NITRITE(N) CONCENTRATION(MG/L)

STATION 04

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.53642E-03 | 0.17881E-03 | 275.09 | 0.11197E-25 |
| STRATM | 1 | 0.48000E-04 | 0.48000E-04 | 73.846 | 0.12635E-09 |
| SL *ST | 3 | 0.11483E-03 | 0.38278E-04 | 58.889 | 0.10061E-13 |
| ERROR | 40 | 0.26000E-04 | 0.65000E-06 | | |
| TOTAL | 47 | 0.72525E-03 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0430 | 0.0405 | 0.0382 | 0.0388 | 0.0401 | 0.0411 |
| | 0.0000 | 0.0010 | 0.0004 | 0.0010 | 0.0020 | 0.0039 |
| LOWER STRATUM | 0.0503 | 0.0412 | 0.0383 | 0.0387 | 0.0421 | |
| | 0.0000 | 0.0007 | 0.0005 | 0.0005 | 0.0050 | |
| SLICE | 0.0467 | 0.0408 | 0.0383 | 0.0387 | | |
| | 0.0039 | 0.0009 | 0.0004 | 0.0007 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ----- | | | |
| GROUP 02 | | ------ | | |
| GROUP 03 | | | ---------- | |

SLICE X STRATUM INTERACTION

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN ELEMENTS

4.521

GROUPS OF MEANS

| ELEMENT | 2 | 1 | 4 | 3 | 7 | 8 | 6 | 5 |
|---|---|---|---|---|---|---|---|---|
| GROUP 01 | ------ | | | | | | | |
| GROUP 02 | | ------- | | | | | | |
| GROUP 03 | | | ---------- | | | | | |
| GROUP 04 | | | | | ---------- | | | |

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.14508E-02 | 0.48361E-03 | 341.37 | 0.17952E-27 |
| STRATM | 1 | 0.36750E-04 | 0.36750E-04 | 25.941 | 0.87922E-05 |
| SL *ST | 3 | 0.33417E-04 | 0.11139E-04 | 7.8627 | 0.30613E-03 |
| ERROR | 40 | 0.56667E-04 | 0.14167E-05 | | |
| TOTAL | 47 | 0.15777E-02 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0538 | 0.0465 | 0.0405 | 0.0410 | 0.0455 | 0.0446 |
| | 0.0026 | 0.0005 | 0.0012 | 0.0006 | 0.0057 | 0.0058 |
| LOWER STRATUM | 0.0535 | 0.0420 | 0.0400 | 0.0393 | 0.0437 | |
| | 0.0012 | 0.0000 | 0.0006 | 0.0005 | 0.0059 | |
| SLICE | 0.0537 | 0.0443 | 0.0403 | 0.0402 | | |
| | 0.0019 | 0.0024 | 0.0009 | 0.0010 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ------ | | | |
| GROUP 02 | | ------ | | |
| GROUP 03 | | | ---------- | |

SLICE X STRATUM INTERACTION

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN ELEMENTS

4.521

GROUPS OF MEANS

| ELEMENT | 1 | 2 | 3 | 4 | 7 | 5 | 6 | 8 |
|---|---|---|---|---|---|---|---|---|
| GROUP 01 | ---------- | | | | | | | |
| GROUP 02 | | | ------ | | | | | |
| GROUP 03 | | | | | ---------- | | | |
| GROUP 04 | | | | | | ---------- | | |

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF NITRATE PLUS NITRITE(N) CONCENTRATION(MG/L)

STATION 05

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.16556E-03 | 0.55188E-04 | 55.418 | 0.26493E-13 |
| STRATM | 1 | 0.22688E-04 | 0.22688E-04 | 22.782 | 0.24329E-04 |
| SL *ST | 3 | 0.24896E-04 | 0.82986E-05 | 8.3333 | 0.20051E-03 |
| ERROR | 40 | 0.39833E-04 | 0.99583E-06 | | |
| TOTAL | 47 | 0.25298E-03 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0442 | 0.0423 | 0.0395 | 0.0392 | 0.0413 | 0.0424 |
| | 0.0004 | 0.0005 | 0.0005 | 0.0008 | 0.0022 | 0.0039 |
| LOWER STRATUM | 0.0450 | 0.0430 | 0.0397 | 0.0430 | 0.0435 | |
| | 0.0009 | 0.0006 | 0.0005 | 0.0023 | 0.0049 | |
| SLICE | 0.0458 | 0.0427 | 0.0396 | 0.0428 | | |
| | 0.0008 | 0.0007 | 0.0005 | 0.0071 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 4 | 3 |
|---|---|---|---|---|
| GROUP 01 | ----- | | | |
| GROUP 02 | | ------ | | |
| | | | ------ | |
| | | | | ------ |

SLICE X STRATUM INTERACTION

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN ELEMENTS

4.521

GROUPS OF MEANS

| ELEMENT | 2 | 1 | 4 | 8 | 3 | 6 | 5 | 7 |
|---|---|---|---|---|---|---|---|---|
| GROUP 01 | ---------- | | | | | | | |
| GROUP 02 | | ---------- | | ---------- | | | | |
| GROUP 03 | | | | | | ---------- | | |

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.99408E-03 | 0.33136E-03 | 141.51 | 0.27735E-20 |
| STRATM | 1 | 0.40833E-05 | 0.40833E-05 | 1.7438 | 0.19417 |
| SL *ST | 3 | 0.62083E-04 | 0.20694E-04 | 8.8375 | 0.12860E-03 |
| ERROR | 40 | 0.93667E-04 | 0.23417E-05 | | |
| TOTAL | 47 | 0.11539E-02 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0503 | 0.0490 | 0.0457 | 0.0407 | 0.0464 | 0.0467 |
| | 0.0012 | 0.0006 | 0.0019 | 0.0008 | 0.0040 | 0.0050 |
| LOWER STRATUM | 0.0540 | 0.0505 | 0.0432 | 0.0403 | 0.0470 | |
| | 0.0023 | 0.0023 | 0.0015 | 0.0005 | 0.0058 | |
| SLICE | 0.0521 | 0.0498 | 0.0444 | 0.0405 | | |
| | 0.0026 | 0.0018 | 0.0021 | 0.0007 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ----- | ------ | | |
| GROUP 02 | | | ------ | |
| GROUP 03 | | | | ------ |
| GROUP 04 | | | | |

SLICE X STRATUM INTERACTION

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN ELEMENTS

4.521

GROUPS OF MEANS

| ELEMENT | 2 | 4 | 1 | 3 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| GROUP 01 | ----- | | | | | | | |
| GROUP 02 | | ---------- | | ---------- | | | | |
| GROUP 03 | | | | | ---------- | | | |
| GROUP 04 | | | | | | ---------- | | |
| GROUP 05 | | | | | | | ---------- | |

# APPENDIX IV

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF AMMONIA(N) CONCENTRATION(MG/L)

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 2 | 0.14778E-04 | 0.73889E-05 | 2.0978 | 0.15728 |
| ERROR | 15 | 0.52833E-04 | 0.35222E-05 | | |
| TOTAL | 17 | 0.67611E-04 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | CROSS-SECTION |
|---|---|---|---|---|
| UPPER STRATUM | 0.0033 | 0.0040 | 0.0055 | 0.0043 |
| | 0.0014 | 0.0018 | 0.0023 | 0.0019 |

GROUPS OF MEANS

| | 1 | 2 | 3 |
|---|---|---|---|
| GROUP 01 | ---------- | | |

STATION 01

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | ERROR | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.13092E-03 | 0.43639E-04 | 0.92488 | 0.43758 |
| STRATM | 1 | 0.37408E-03 | 0.37408E-03 | 7.9283 | 0.75191E-02 |
| SL *ST | 3 | 0.84917E-04 | 0.28306E-04 | 0.59991 | 0.61884 |
| ERROR | 40 | 0.18873E-02 | 0.47183E-04 | | |
| TOTAL | 47 | 0.24773E-02 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.0072 | 0.0143 | 0.0080 | 0.0122 | 0.0104 | 0.0076 |
| | 0.0093 | 0.0068 | 0.0028 | 0.0148 | 0.0094 | 0.0073 |
| LOWER STRATUM | 0.0048 | 0.0050 | 0.0040 | 0.0055 | 0.0083 | |
| | 0.0019 | 0.0019 | 0.0017 | 0.0026 | 0.0019 | |
| SLICE | 0.0060 | 0.0097 | 0.0060 | 0.0088 | | |
| | 0.0065 | 0.0068 | 0.0030 | 0.0107 | | |

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ---------- | | | |

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF AMMONIA(N) CONCENTRATION(MG/L)

STATION 02

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 1.0193 | 0.33973 | 1996.3 | 0.15699E-42 |
| STRATM | 1 | 0.40252E-03 | 0.40252E-03 | 2.3649 | 0.13196 |
| SL *ST | 3 | 0.32990E-03 | 0.10997E-03 | 0.64608 | 0.59001 |
| ERROR | 40 | 0.68082E-02 | 0.17020E-03 | | |
| TOTAL | 47 | 1.0269 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.3700 | 0.1060 | 0.0130 | 0.0080 | 0.1243 | 0.1272 |
| | 0.0167 | 0.0139 | 0.0074 | 0.0062 | 0.1507 | 0.1478 |
| LOWER STRATUM | 0.3700 | 0.1155 | .0253 | 0.0093 | 0.1300 | |
| | 0.0126 | 0.0169 | 0.0170 | 0.0077 | 0.1480 | |
| SLICE | 0.3700 | 0.1107 | 0.0192 | 0.0086 | | |
| | 0.0142 | 0.0155 | 0.0141 | 0.0067 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ----- | | | |
| GROUP 02 | | ----- | | |
| GROUP 03 | | | ---------- | |
| GROUP 04 | | | | |

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 2.7283 | | 8890.9 | 0.18505E-55 |
| STRATM | 1 | 0.47402E-02 | 0.47402E-02 | 46.342 | 0.34799E-07 |
| SL *ST | 3 | 0.78602E-02 | 0.26201E-02 | 25.615 | 0.20621E-08 |
| ERROR | 40 | 0.40915E-02 | 0.10229E-03 | | |
| TOTAL | 47 | 2.7450 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.6150 | 0.1752 | 0.0143 | 0.0273 | 0.2080 | 0.2179 |
| | 0.0152 | 0.0096 | 0.0043 | 0.0088 | 0.2488 | 0.2417 |
| LOWER STRATUM | 0.6150 | 0.2083 | 0.0693 | 0.0187 | 0.2278 | |
| | 0.0105 | 0.0117 | 0.0093 | 0.0080 | 0.2393 | |
| SLICE | 0.6150 | 0.1917 | 0.0418 | 0.0230 | | |
| | 0.0124 | 0.0201 | 0.0295 | 0.0092 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ------ | | | |
| GROUP 02 | | ------ | | |
| GROUP 03 | | | ------ | |
| GROUP 04 | | | | ------ |

SLICE X STRATUM INTERACTION

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN ELEMENTS

4.521

GROUPS OF MEANS

| ELEMENT | 1 | 2 | 4 | 3 | 6 | 7 | 8 | 5 |
|---|---|---|---|---|---|---|---|---|
| GROUP 01 | ---------- | | | | | | | |
| GROUP 02 | | | ------ | | | | | |
| GROUP 03 | | | | ------ | | | | |
| GROUP 04 | | | | | ------ | | | |
| GROUP 05 | | | | | | ---------- | | |

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF AMMONIA(N) CONCENTRATION(MG/L)

STATION 03

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.42230 | 0.14077 | 1223.0 | 0.25982E-38 |
| STRATM | 1 | 0.44408E-03 | 0.44408E-03 | 3.8582 | 0.56477E-01 |
| SL *ST | 3 | 0.54944E-02 | 0.18315E-02 | 15.912 | 0.58195E-06 |
| ERROR | 40 | 0.46040E-02 | 0.11510E-03 | | |
| TOTAL | 47 | 0.43284 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.2283 | 0.1618 | 0.0348 | 0.0135 | 0.1096 | 0.1066 |
| | 0.0214 | 0.0065 | 0.0094 | 0.0071 | 0.0916 | 0.0960 |
| LOWER STRATUM | 0.2550 | 0.1307 | 0.0178 | 0.0107 | 0.1035 | |
| | 0.0105 | 0.0109 | 0.0066 | 0.0034 | 0.1020 | |
| SLICE | 0.2417 | 0.1463 | 0.0263 | 0.0121 | | |
| | 0.0213 | 0.0184 | 0.0118 | 0.0055 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ----- | | | |
| GROUP 02 | | ----- | | |
| GROUP 03 | | | ----- | |
| GROUP 04 | | | | ----- |

SLICE X STRATUM INTERACTION

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN ELEMENTS

4.521

GROUPS OF MEANS

| ELEMENT | 2 | 1 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| GROUP 01 | ---- | | | | | | | |
| GROUP 02 | | ------ | | | | | | |
| GROUP 03 | | | ------ | | | | | |
| GROUP 04 | | | | ------ | | | | |
| GROUP 05 | | | | | ---------- | | | |
| GROUP 06 | | | | | | ---------- | | |

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.68798 | 0.22933 | 1405.6 | 0.16527E-39 |
| STRATM | 1 | 0.45633E-03 | 0.45633E-03 | 2.7970 | 0.10224 |
| SL *ST | 3 | 0.31470E-01 | 0.10490E-01 | 64.296 | 0.25535E-14 |
| ERROR | 40 | 0.65260E-02 | 0.16315E-03 | | |
| TOTAL | 47 | 0.72643 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.3283 | 0.1253 | 0.0442 | 0.0288 | 0.1317 | 0.1347 |
| | 0.0041 | 0.0069 | 0.0123 | 0.0154 | 0.1223 | 0.1243 |
| LOWER STRATUM | 0.3000 | 0.2200 | 0.0212 | 0.0102 | 0.1378 | |
| | 0.0261 | 0.0127 | 0.0022 | 0.0024 | 0.1289 | |
| SLICE | 0.3142 | 0.1727 | 0.0327 | 0.0195 | | |
| | 0.0231 | 0.0504 | 0.0147 | 0.0143 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ------ | | | |
| GROUP 02 | | ------ | | |
| GROUP 03 | | | ---------- | |

SLICE X STRATUM INTERACTION

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN ELEMENTS

4.521

GROUPS OF MEANS

| ELEMENT | 1 | 2 | 4 | 3 | 5 | 7 | 6 | 8 |
|---|---|---|---|---|---|---|---|---|
| GROUP 01 | ------ | | | | | | | |
| GROUP 02 | | ------ | | | | | | |
| GROUP 03 | | | ------ | | | | | |
| GROUP 04 | | | | ------ | | | | |
| GROUP 05 | | | | | ---------- | | | |
| GROUP 06 | | | | | | ---------- | | |

TABLE 04. RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF AMMONIA(N) CONCENTRATION(MG/L)

STATION 04

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.27343 | 0.91142E-01 | 841.79 | 0.41266E-35 |
| STRATM | 1 | 0.10925E-02 | 0.10925E-02 | 10.091 | 0.28697E-02 |
| SL *ST | 3 | 0.26379E-02 | 0.87930E-03 | 8.1213 | 0.24238E-03 |
| ERROR | 40 | 0.43308E-02 | 0.10827E-03 | | |
| TOTAL | 47 | 0.28149 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.1945 | 0.1467 | 0.0500 | 0.0267 | 0.1045 | 0.1092 |
| | 0.0050 | 0.0099 | 0.0064 | 0.0124 | 0.0707 | 0.0774 |
| LOWER STRATUM | 0.2283 | 0.1540 | 0.0530 | 0.0207 | 0.1140 | |
| | 0.0160 | 0.0131 | 0.0092 | 0.0060 | 0.0848 | |
| SLICE | 0.2114 | 0.1503 | 0.0515 | 0.0237 | | |
| | 0.0210 | 0.0117 | 0.0077 | 0.0098 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES 3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ----- | | | |
| GROUP 02 | | ------ | | |
| GROUP 03 | | | ------ | |
| GROUP 04 | | | | ------ |

SLICE X STRATUM INTERACTION

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN ELEMENTS 4.521

GROUPS OF MEANS

| ELEMENT | 2 | 1 | 4 | 3 | 6 | 5 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| GROUP 01 | ------ | | | | | | | |
| GROUP 02 | | ------- | | | | | | |
| GROUP 03 | | | ---------- | | | | | |
| GROUP 04 | | | | ---------- | | | | |
| GROUP 05 | | | | | -------- | | | |

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.85318 | 0.28439 | 374.82 | 0.29651E-29 |
| STRATM | 1 | 0.22577E-01 | 0.22577E-01 | 29.756 | 0.27532E-05 |
| SL *ST | 3 | 0.11202 | 0.37338E-01 | 49.211 | 0.17267E-12 |
| ERROR | 40 | 0.30249E-01 | 0.75874E-03 | | |
| TOTAL | 47 | 1.0181 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.3083 | 0.3367 | 0.0395 | 0.0183 | 0.1757 | 0.1540 |
| | 0.0133 | 0.0273 | 0.0118 | 0.0031 | 0.1513 | 0.1472 |
| LOWER STRATUM | 0.3550 | 0.1303 | 0.0297 | 0.0143 | 0.1323 | |
| | 0.0666 | 0.0183 | 0.0151 | 0.0020 | 0.1428 | |
| SLICE | 0.3317 | 0.2335 | 0.0345 | 0.0163 | | |
| | 0.0518 | 0.1100 | 0.0139 | 0.0032 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES 3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ------ | | | |
| GROUP 02 | | ------ | | |
| GROUP 03 | | | ---------- | |

SLICE X STRATUM INTERACTION

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN ELEMENTS 4.521

GROUPS OF MEANS

| ELEMENT | 2 | 3 | 1 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| GROUP 01 | ---------- | | | | | | | |
| GROUP 02 | | | | ---- | | | | |
| GROUP 03 | | | | | ---------- | | | |

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF AMMONIA(N) CONCENTRATION(MG/L)

STATION 05

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.10120 | 0.33733E-01 | 475.42 | 0.29639E-30 |
| STRATM | 1 | 0.38521E-04 | 0.38521E-04 | 0.54289 | 0.46554 |
| SL *ST | 3 | 0.13823E-03 | 0.46076E-04 | 0.64938 | 0.58798 |
| ERROR | 40 | 0.28382E-02 | 0.70954E-04 | | |
| TOTAL | 47 | 0.10421 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.1652 | 0.1408 | 0.0782 | 0.0563 | 0.1097 | 0.1093 |
| | 0.0037 | 0.0038 | 0.0082 | 0.0045 | 0.0461 | 0.0471 |
| LOWER STRATUM | 0.1655 | 0.1435 | 0.0730 | 0.0513 | 0.1090 | |
| | 0.0089 | 0.0147 | 0.0094 | 0.0082 | 0.0488 | |
| SLICE | 0.1653 | 0.1422 | 0.0758 | 0.0543 | | |
| | 0.0065 | 0.0103 | 0.0088 | 0.0068 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ----- | | | |
| GROUP 02 | | ----- | | |
| GROUP 03 | | | ----- | |
| GROUP 04 | | | | ----- |

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.17691 | 0.58971E-01 | 474.00 | 0.31419E-30 |
| STRATM | 1 | 0.27755E-02 | 0.27755E-02 | 22.309 | 0.28475E-04 |
| SL *ST | 3 | 0.20979E-02 | 0.69930E-03 | 5.6208 | 0.25971E-02 |
| ERROR | 40 | 0.49765E-02 | 0.12441E-03 | | |
| TOTAL | 47 | 0.18676 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.1843 | 0.1845 | 0.1053 | 0.0463 | 0.1301 | 0.1225 |
| | 0.0056 | 0.0080 | 0.0106 | 0.0098 | 0.0599 | 0.0630 |
| LOWER STRATUM | 0.1782 | 0.1775 | 0.0673 | 0.0367 | 0.1149 | |
| | 0.0037 | 0.0093 | 0.0242 | 0.0020 | 0.0664 | |
| SLICE | 0.1813 | 0.1810 | 0.0863 | 0.0415 | | |
| | 0.0055 | 0.0090 | 0.0267 | 0.0084 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ---------- | | | |
| GROUP 02 | | | ------ | |
| GROUP 03 | | | | ------ |

SLICE X STRATUM INTERACTION

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN ELEMENTS

4.521

GROUPS OF MEANS

| ELEMENT | 3 | 1 | 2 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| GROUP 01 | ---------- | | | | | | | |
| GROUP 02 | | | | | ------ | | | |
| GROUP 03 | | | | | | ------ | | |
| GROUP 04 | | | | | | | --------- | |

# APPENDIX V

TABLE 05. RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF TOTAL NITROGEN(N) CONCENTRATION(MG/L)

STATION 01

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 2 | 0.93700E-03 | 0.46850E-03 | 2.1247 | 0.15401 |
| ERROR | 15 | 0.33075E-02 | 0.22050E-03 | | |
| TOTAL | 17 | 0.42445E-02 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | CROSS-SECTION |
|---|---|---|---|---|
| UPPER STRATUM | 0.2100 | 0.1940 | 0.1955 | 0.1998 |
| | 0.0174 | 0.0141 | 0.0125 | 0.0158 |

GROUPS OF MEANS

| GROUP 01 | 1 | 2 | 3 |
|---|---|---|---|

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.62229E-04 | 0.20743E-04 | 0.65375E-01 | 0.97741 |
| STRATM | 1 | 0.33167E-02 | 0.33167E-02 | 10.613 | 0.22934E-02 |
| SL *ST | 3 | 0.57440E-03 | 0.19147E-03 | 0.61267 | 0.61077 |
| ERROR | 40 | 0.12501E-01 | 0.31251E-03 | | |
| TOTAL | 47 | 0.16454E-01 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.2082 | 0.1988 | 0.2003 | 0.1962 | 0.2009 | 0.1926 |
| | 0.0279 | 0.0238 | 0.0129 | 0.0278 | 0.0023 | 0.0187 |
| LOWER STRATUM | 0.1798 | 0.1862 | 0.1855 | 0.1855 | 0.1842 | |
| | 0.0057 | 0.0032 | 0.0085 | 0.0099 | 0.0073 | |
| SLICE | 0.1940 | 0.1925 | 0.1929 | 0.1908 | | |
| | 0.0242 | 0.0175 | 0.0130 | 0.0207 | | |

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | | | | |

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF TOTAL NITROGEN(N) CONCENTRATION(MG/L)

STATION 02

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 1.3314 | 0.44379 | 339.31 | 0.21345E-27 |
| STRATM | 1 | 0.32013E-02 | 0.32013E-02 | 2.4404 | 0.12612 |
| SL *ST | 3 | 0.73072E-02 | 0.24357E-02 | 1.8568 | 0.15247 |
| ERROR | 40 | 0.52471E-01 | 0.13118E-02 | | |
| TOTAL | 47 | 1.3944 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | C.6173 | 0.3185 | 0.1998 | 0.2012 | 0.3342 | 0.3423 |
| | C.0107 | 0.0273 | 0.0141 | 0.0324 | 0.1754 | 0.1722 |
| LOWER STRATUM | C.6187 | 0.3388 | 0.2543 | 0.1903 | 0.3505 | |
| | 0.0350 | C.0530 | 0.0632 | 0.0189 | 0.1724 | |
| SLICE | C.618C | C.3287 | 0.2271 | 0.1958 | | |
| | 0.0247 | 0.0416 | 0.0521 | 0.0259 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ----- | | | |
| GROUP 02 | | ----- | | |
| GROUP 03 | | | ---------- | |

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 2.6498 | 0.88325 | 3130.5 | 0.20387E-46 |
| STRATM | 1 | 0.25230E-02 | 0.25230E-02 | 8.9423 | 0.47507E-02 |
| SL *ST | 3 | 0.13952E-01 | 0.46507E-02 | 16.484 | 0.39803E-06 |
| ERROR | 40 | 0.11286E-01 | 0.28214E-03 | | |
| TOTAL | 47 | 2.6775 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | C.8083 | 0.3612 | 0.2047 | 0.2350 | 0.4023 | 0.4095 |
| | C.0125 | 0.0090 | 0.0129 | 0.0221 | 0.2473 | C.2387 |
| LOWER STRATUM | 0.7973 | 0.3923 | 0.2665 | 0.0210 | 0.4168 | |
| | C.0130 | 0.C084 | 0.0318 | 0.0107 | 0.2349 | |
| SLICE | C.8028 | 0.3768 | 0.2356 | 0.2230 | | |
| | 0.0135 | 0.0183 | 0.0397 | 0.0207 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ------ | | | |
| GROUP 02 | | ------ | | |
| GROUP 03 | | | ---------- | |

SLICE X STRATUM INTERACTION

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN ELEMENTS

4.521

GROUPS OF MEANS

| ELEMENT | 1 | 2 | 4 | 3 | 6 | 7 | 8 | 5 |
|---|---|---|---|---|---|---|---|---|
| GROUP 01 | ---------- | | | | | | | |
| GROUP 02 | | | ------ | | | | | |
| GROUP 03 | | | | ------ | | | | |
| GROUP 04 | | | | | ---- | | | |
| GROUP 05 | | | | | | ---------- | | |

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF TOTAL NITROGEN(N) CONCENTRATION(MG/L)

STATION 03

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.69632 | 0.23211 | 272.04 | 0.13842E-25 |
| STRATM | 1 | 0.27000E-02 | 0.27000E-02 | 3.1645 | 0.82855E-01 |
| SL *ST | 3 | 0.33732E-02 | 0.11244E-02 | 1.3178 | 0.28199 |
| ERROR | 40 | 0.34128E-01 | 0.85321E-03 | | |
| TOTAL | 47 | 0.73652 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.5012 | 0.3583 | 0.2397 | 0.2065 | 0.3264 | 0.3189 |
| | 0.0252 | 0.0298 | 0.0386 | 0.0316 | 0.1217 | 0.1252 |
| LOWER STRATUM | 0.5112 | 0.3258 | 0.2118 | 0.1968 | 0.3114 | |
| | 0.0253 | 0.0371 | 0.0233 | 0.0161 | 0.1307 | |
| SLICE | 0.5062 | 0.3421 | 0.2257 | 0.2017 | | |
| | 0.0246 | 0.0362 | 0.0337 | 0.0244 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 4 | 3 |
|---|---|---|---|---|
| GROUP 01 | ----- | | | |
| GROUP 02 | | ----- | | |
| GROUP 03 | | | ---------- | |
| GROUP 04 | | | | |

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.96246 | 0.32082 | 597.92 | 0.33924E-32 |
| STRATM | 1 | 0.30502E-03 | 0.30502E-03 | 0.56847 | 0.45528 |
| SL *ST | 3 | 0.42950E-01 | 0.14317E-01 | 26.682 | 0.12084E-08 |
| ERROR | 40 | 0.21463E-01 | 0.53656E-03 | | |
| TOTAL | 47 | 1.0272 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.5823 | 0.3262 | 0.2672 | 0.2402 | 0.3540 | 0.3565 |
| | 0.0129 | 0.0205 | 0.0397 | 0.0346 | 0.1410 | 0.1478 |
| LOWER STRATUM | 0.5758 | 0.4315 | 0.2182 | 0.2105 | 0.3590 | |
| | 0.0163 | 0.0167 | 0.0084 | 0.0178 | 0.1574 | |
| SLICE | 0.5791 | 0.3788 | 0.2427 | 0.2253 | | |
| | 0.0144 | 0.0578 | 0.0374 | 0.0305 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 4 | 3 |
|---|---|---|---|---|
| GROUP 01 | ------ | | | |
| GROUP 02 | | ------ | | |
| GROUP 03 | | | ---------- | |

SLICE X STRATUM INTERACTION

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN ELEMENTS

4.521

GROUPS OF MEANS

| ELEMENT | 1 | 2 | 4 | 3 | 5 | 7 | 6 | 8 |
|---|---|---|---|---|---|---|---|---|
| GROUP 01 | ---------- | | | | | | | |
| GROUP 02 | | | ------ | | | | | |
| GROUP 03 | | | | ------ | | | | |
| GROUP 04 | | | | | ---------- | | | |
| GROUP 05 | | | | | | ---------- | | |

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF TOTAL NITROGEN(N) CONCENTRATION(MG/L)

STATION 04

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.29903 | 0.99678E-01 | 88.765 | 0.19429E-15 |
| STRATM | 1 | 0.21735E-02 | 0.21735E-02 | 1.9356 | 0.17184 |
| SL *ST | 3 | 0.91852E-02 | 0.30617E-02 | 2.7265 | 0.56719E-01 |
| ERROR | 40 | 0.44918E-01 | 0.11229E-02 | | |
| TOTAL | 47 | 0.35531 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.3865 | 0.3545 | 0.2387 | 0.2372 | 0.3042 | 0.3111 |
| | 0.0043 | 0.0420 | 0.0160 | 0.0442 | 0.0747 | 0.0869 |
| LOWER STRATUM | 0.4235 | 0.3897 | 0.2520 | 0.2055 | 0.3177 | |
| | 0.0269 | 0.0552 | 0.0307 | 0.0167 | 0.0988 | |
| SLICE | 0.4050 | 0.3721 | 0.2453 | 0.2213 | | |
| | 0.0266 | 0.0502 | 0.0243 | 0.0358 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ---------- | | | |
| GROUP 02 | | | ---------- | |
| GROUP 03 | | | | |

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.55135 | 0.18378 | 608.62 | 0.23980E-32 |
| STRATM | 1 | 0.12097E-01 | 0.12097E-01 | 40.060 | 0.16280E-06 |
| SL *ST | 3 | 0.27712E-01 | 0.92375E-02 | 30.591 | 0.19122E-09 |
| ERROR | 40 | 0.12079E-01 | 0.30197E-03 | | |
| TOTAL | 47 | 0.60323 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | 2 | 3 | 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.4643 | 0.4493 | 0.2403 | 0.2155 | 0.3424 | 0.3265 |
| | 0.0082 | 0.0217 | 0.0158 | 0.0064 | 0.1182 | 0.1133 |
| LOWER STRATUM | 0.4702 | 0.3353 | 0.2365 | 0.2005 | 0.3106 | |
| | 0.0127 | 0.0180 | 0.0316 | 0.0100 | 0.1084 | |
| SLICE | 0.4673 | 0.3923 | 0.2384 | 0.2080 | | |
| | 0.0106 | 0.0625 | 0.0239 | 0.0112 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ------ | | | |
| GROUP 02 | | ------ | | |
| GROUP 03 | | | ------ | |
| GROUP 04 | | | | ------ |

SLICE X STRATUM INTERACTION

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN ELEMENTS

4.521

GROUPS OF MEANS

| ELEMENT | 2 | 1 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| GROUP 01 | ---------- | | | | | | | |
| GROUP 02 | | | | ------ | | | | |
| GROUP 03 | | | | | ---------- | | | |
| GROUP 04 | | | | | | | --------- | |

RESULTS OF ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
ORIGINAL OBSERVATIONS OF TOTAL NITROGEN(N) CONCENTRATION(MG/L)

STATION 05

DECEMBER 09,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.11938 | 0.39792E-01 | 46.186 | 0.46205E-12 |
| STRATM | 1 | 0.20008E-03 | 0.20008E-03 | 0.23223 | 0.63250 |
| SL *ST | 3 | 0.42311E-02 | 0.14104E-02 | 1.6370 | 0.19605 |
| ERROR | 40 | 0.34462E-01 | 0.86156E-03 | | |
| TOTAL | 47 | 0.15827 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.3547 | 0.3490 | 0.2908 | 0.2490 | 0.3109 | 0.3103 |
| | 0.0160 | 0.0307 | 0.0273 | 0.0193 | 0.0499 | 0.0572 |
| LOWER STRATUM | 0.3740 | 0.3520 | 0.2583 | 0.2428 | 0.3098 | |
| STANDARD DEVIATION | 0.0377 | 0.0478 | 0.0209 | 0.0210 | 0.0648 | |
| SLICE | 0.3643 | 0.3505 | 0.2746 | 0.2519 | | |
| STANDARD DEVIATION | 0.0294 | 0.0383 | 0.0287 | 0.0278 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ---------- | | | |
| GROUP 02 | | | ---------- | |

DECEMBER 10,1976

ANALYSIS OF VARIANCE

| SOURCE | DF | SUM SQ | MEAN SQ | F-VALUE | PROB |
|---|---|---|---|---|---|
| SLICE | 3 | 0.19255 | 0.64182E-01 | 84.779 | 0.23592E-15 |
| STRATM | 1 | 0.46252E-03 | 0.46252E-03 | 0.61095 | 0.43903 |
| SL *ST | 3 | 0.26952E-02 | 0.89841E-03 | 1.1867 | 0.32699 |
| ERROR | 40 | 0.30282E-01 | 0.75705E-03 | | |
| TOTAL | 47 | 0.22599 | | | |

CONCENTRATION
MEAN AND STANDARD DEVIATION

| | SLICE 1 | SLICE 2 | SLICE 3 | SLICE 4 | STRATUM | CROSS-SECTION |
|---|---|---|---|---|---|---|
| UPPER STRATUM | 0.3895 | 0.3867 | 0.2833 | 0.2363 | 0.2363 | 0.3208 |
| | 0.0081 | 0.0160 | 0.0061 | 0.0147 | 0.0147 | 0.0693 |
| LOWER STRATUM | 0.3850 | 0.3603 | 0.2990 | 0.2267 | 0.2267 | |
| STANDARD DEVIATION | 0.0077 | 0.0125 | 0.0722 | 0.0074 | 0.0074 | |
| SLICE | 0.3872 | 0.3735 | 0.2912 | 0.2315 | | |
| STANDARD DEVIATION | 0.0078 | 0.0194 | 0.0495 | 0.0122 | | |

MULTIPLE RANGE TEST

STUDENTIZED RANGE FOR TUKEY'S TEST ALPHA=0.05

DIFFERENCES BETWEEN CONCENTRATION MEANS OBSERVED IN SLICES

3.791

GROUPS OF MEANS

| SLICE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| GROUP 01 | ---------- | | | |
| GROUP 02 | | | ------ | |
| GROUP 03 | | | | ------ |

CANADA-BRITISH COLUMBIA

OKANAGAN BASIN IMPLEMENTATION AGREEMENT

# NUTRIENT LOADINGS - OKANAGAN BASIN

REPORT NO. 1

## OKANAGAN RIVER AT PENTICTON

## PRELIMINARY SURVEY AND STATION SELECTION

L.J. Zeman, W.E. Erlebach
and H. Olav Slaymaker

INLAND WATERS DIRECTORATE

VANCOUVER

December 1977

CANADA - BRITISH COLUMBIA OKANAGAN BASIN

IMPLEMENTATION AGREEMENT

# NUTRIENT LOADINGS - OKANAGAN BASIN

# OKANAGAN RIVER AT PENTICTON

# PRELIMINARY SURVEY AND STATION SELECTION

# PROGRESS REPORT

L.J. Zeman, W.E. Erlebach
and H. Olav Slaymaker

INLAND WATERS DIRECTORATE

VANCOUVER

December 1977

## N O T I C E

This report was prepared for the Implementation Board under the terms of the Canada-British Columbia Okanagan Basin Implementation Agreement. The information contained in this report is preliminary and subject to revision. The Implementation Board does not necessarily concur with opinions expressed in the report.

Office of the Program Coordinator

P.O. Box 458, Penticton, B.C.

V2A 6K6

Published _____

CANADA - BRITISH COLUMBIA OKANAGAN BASIN
IMPLEMENTATION AGREEMENT

# ESTIMATES OF NUTRIENT LOAD CARRIED BY THE OKANAGAN RIVER INTO OSOYOOS LAKE

## PART I

PART IA DATA SUMMARY - MAINSTEM RIVER, TRIBUTARIES AND MUNICIPAL OUTFALLS

PART IB DETAILED REPORT - OLIVER-OSOYOOS REACH

L. John Zeman and H. Olav Slaymaker

INLAND WATERS DIRECTORATE

VANCOUVER

June 1982

N O T I C E

This report was prepared for the Implementation Board under the terms of the Canada-British Columbia Okanagan Basin Implementation Agreement. The information contained in this report is preliminary and subject to revision. The implementation Board does not necessarily concur with opinions expressed in this report.

Office of the Program Coordinator
P.O. Box 458, Penticton, B.C.
V2A 6K6

Published

CANADA - BRITISH COLUMBIA OKANAGAN BASIN
IMPLEMENTATION AGREEMENT

# ESTIMATES OF NUTRIENT LOAD CARRIED BY THE OKANAGAN RIVER INTO OSOYOOS LAKE

## PART II

## Statistical Characteristics of Nutrient Concentration and Load Okanagan River Near Oliver

DATA REPORT

L. John Zeman and H. Olav Slaymaker

INLAND WATERS DIRECTORATE

VANCOUVER

June 1982

CANADA - BRITISH COLUMBIA OKANAGAN BASIN
IMPLEMENTATION AGREEMENT

# Statistical Characteristics of Nutrient Concentration and Load Okanagan River Below Okanagan Lake

DATA REPORT

L. John Zeman

INLAND WATERS DIRECTORATE

VANCOUVER

September 1982

## N O T I C E

This report was prepared for the Implementation Board under the terms of the Canada-British Columbia Okanagan Basin Implementation Agreement. The information contained in this report is preliminary and subject to revision. The Implementation Board does not necessarily concur with opinions expressed in this report.

Office of the Program Coordinator
P.O. Box 458, Penticton, B.C.
V2A 6K6

Published

OKANAGAN
BASIN
IMPLEMENTATION
BOARD

CANADA
E.M. CLARK, VICE-CHAIRMAN
B.A. HESKIN

BRITISH COLUMBIA
T.H. OXLAND, CHAIRMAN
T.F. MOORE

LETTER OF TRANSMITTAL

September 1982.

The Honourable John Roberts,
Minister of the Environment,
Ottawa, Canada.

The Honourable Stephen Rogers,
Minister of Environment,
Victoria, British Columbia.

Dear Sirs:

On February 9, 1976, the Governments of Canada and British Columbia entered into a joint undertaking to implement a plan for the development and management of water resources in the Okanagan Basin. This undertaking was designated as the Okanagan Basin Implementation Agreement. The "Parties" to the Agreement subsequently each appointed two members to form the Implementation Board. This Board was made responsible for the implementation and administration of the various cost-shared programs referred to in the agreement, and for maintaining coordination with other departments and authorities responsible for non-cost shared programs. The time frame of the Agreement was for five years, to February 9, 1981. This time frame was subsequently extended to September 30, 1982.

The Implementation Board is pleased to submit the Report on the Okanagan Basin Implementation Agreement which includes recommendations for the ongoing management of water and related resources in the Okanagan Basin through 1980. A summary of this report is also enclosed.

The Board wishes to express its appreciation for the support it has received from the Governments and their representative agencies.

Respectfully submitted,

"E.M. Clark"
E.M. Clark, Vice-Chairman
Regional Director,
Inland Waters Directorate,
Environment Canada.

"T.H. Oxland"
T.H. Oxland, Chairman,
Regional Director, Okanagan Region,
Ministry of Environment,
British Columbia.

"B.A. Heskin"
B.A. Heskin,
Regional Director,
Environmental Protection Service,
Environment Canada.

"T.F. Moore"
T.F. Moore,
Assistant Deputy Minister,
Ministry of Municipal Affairs,
British Columbia.

Canada - British Columbia Okanagan Basin Implementation Agreement

RESPONSIBILITIES L. John Zeman

Responsible for developing and implementing nutrient loading program, assigned to Water Quality Branch, under the five-year Canada British Columbia Okanagan Basin Implementation Agreement. (Feb 1976 - to Sep 1982) The program responsibilities included:

(a) participation in the provincial-federal committees formed for the implementation of the water quality study under the Agreement,

(b) direct involvement in formulating study objectives and outlining methodologies used for field measurements and interpretation of results,

(c) ensuring the cost effectiveness of all operations during the study program by estimating and justifying the need for financial resources which have been used since 1976 to the end of September 30, 1982 in the amount of $287,863.00,

(d) completion of all scientific reports, as a part of the Water Quality Branch commitment to the Agreement, by definite deadlines specified by the Implementation Board, and publication of articles in scientific journals.

Emphasis was placed on the:

(a) development of sampling methods leading to a better understanding of processes which govern dispersion of pollutants in the Okanagan River reach below major point and non-point sources,

(b) establishment of confidence limits on water quality data acquired for the purpose of managing water resources,

(c) assessment of the effectiveness of remedial actions for resolving water use conflicts, and

(d) development of recommendations for ongoing long-term water quality monitoring program in the Okanagan Basin.

Each of these four emphases are reflected in the topics of accomplished reports and articles (see Publications).

Canada - British Columbia Okanagan Basin Implementation Agreement

REPORTS


Zeman, J.L. 1982. Statistical Characteristics of Nutrient Concentrations and Loads, Okanagan River below Okanagan Lake 1976-1980, Data Report, Inland Waters Directorate, Vancouver, B.C. pp. 1-580.

Zeman, L. John and H. Olav Slaymaker. 1982. Estimates of Nutrients Loads Carried by the Okanagan River into Osoyoos Lake. Report for the Okanagan Basin Implementation Board. Inland Waters Directorate, Vancouver, B.C. Part I pp. 1-98 and Part II, pp. 1-507.

Zeman, L.J. and O. Slaymaker. 1981. Determination of Nutrient Loads Into and Out of Skaha Lake. Report for Okanagan Basin Implementation Board, Inland Waters Directorate, Vancouver, B.C., pp. 1-191.

Zeman, L.J. and and W.E. Erlebach. 1981. Mixing of Chemical Substances in Rivers with Reference to Okanagan River at Penticton. Internal Report, for the Department of Justice, Water Quality Branch, Inland Waters Directorate, Vancouver, B.C., pp. 1-9.

Zeman, L. John. 1981. Field Sampling Methods and Precision of Nutrient Transport Estimation, Okanagan River, B.C., Proceedings of the Field Quality Assurance Workshop Water Quality Branch, Inland Waters Directorate, November 18-19, 1982, Canada Centre for Inland Waters, Burlington, Ontario, pp. 85-134.

Zeman, L.J., W.E. Erlebach and H. Olav Slaymaker. 1977. Nutrient Loadings - Okanagan Basin. Progress Report. Okanagan River at Penticton. Preliminary Survey and Station Selection. Report for the Okanagan Basin Implementation Board. Inland Waters Directorate, Vancouver, B.C. pp. 1-95.


ARTICLES


Zeman, L.J. and O. Slaymaker. 1981. A Method for Nutrient Transport Estimation. In: H.G. Stefan edt., Proceedings of the Symposium on Surface-Water Impoundments, Minneapolis, Vol. I, June 1980. Publish by American Society of Civil Engineers. pp. 335-344.

Zeman, L.J. and H.O. Slaymaker. 1981. Nutrient Flux Estimate by Partial Load Method. Journal of the Environmental Engineering Division, ASCE, Vol. 107, No. EE2, April. pp. 425-428.

The Canada-British Columbia Okanagan Basin Agreement ended in September 1982. Results from the Nutrient Loading Program which was assigned to the Water Quality Branch, Pacific and Yukon Region, under this Agreement, are described in a number of reports and articles listed on an attached sheet.

These reports are based on extensive data collected in the southern Okanagan River Basin during the period from 1976 to 1980. The Nutrient Loading Study was designed to assess changes, which could be attributed to reduced loads from municipal waste treatment plants, in nutrient loading to two mainstem lakes on the Okanagan River. The data set, comprising four to five thousand measurements of each of six variables, provides a unique opportunity to advance the technique of monitoring design for trend measurement and for developing realistic water quality objectives.